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ANALYSIS OF POLLUTION FROM MARINE ENGINES AND EFFECTS ON THE ENVIRONMENT

Boating Industry Associations

Prepared for:

National Environmental Research Center
Environmental Control Technology Corporation

June 1975

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The objective of this study was "to obtain sufficient laboratory and field data to be able to predict the number of outboard engines which can be operated on any particular body of water without causing adverse effects on the aquatic environment." To achieve this objective four small natural bodies of water were subjected to outboard engine emissions three times greater than saturation (maximum) levels occurring under "real world" boating conditions. These natural water bodies were stressed at these high levels with outboard engine exhaust emissions for a period of three years. The study showed that there were no "dramatic" or acute changes in the physical, chemical or biological characteristics of the water or sediments of the test lakes at these high stressing levels. This report was submitted in fulfillment of Project Number 15020 GPG and Grant Number R-801799 by the Boating Industry Associations under the partial sponsorship of the Environmental Protection Agency.

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By

Environmental Control Technology Corporation
Ann Arbor, Michigan 48104

Grant No. R-801799
Program Element No. 1BB038

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333

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The National Environmental Research Center, Cincinnati, has reviewed this report and approved it for publication in order that the data may be made widely available and serve as a basis for future studies by others, should they be desired. Approval does not signify that the contents necessarily reflect the views and policies of the U.S. Environmental Protection Agency nor does mention of trade names or commercial products constitute endorsement or recommendation for their use.

FOREWORD

Man and his environment must be protected from the adverse effects of pesticides, radiation, noise and other forms of pollution and the unwise management of solid waste. Efforts to protect the environment require a focus that recognizes the interplay between the components of our physical environment--air, water and land. The National Environmental Research Centers provide the multidisciplinary focus through programs engaged in

- studies on the effects of environmental contaminants on man and the biosphere, and
- a search for ways to prevent contamination and to recycle valuable resources.

The northern lakes, southern lakes and laboratory studies were conducted by independent consultants who were subcontractors to the Boating Industry Associations. The project design was approved by the U. S. Environmental Protection Agency and monitored during the course of the study by EPA personnel. As a result of the studies and the contractors' analysis of the data, no significant environmental impacts from outboard motor boating activity were found under the study conditions. However, since it was impossible in this study to cover fully all the diverse factors which may be impacted by emissions from outboard motors, care should be taken in extrapolating the results to situations other than those covered by this specific study. These data are being presented in order that they may be widely available and serve as a basis for possible future studies by others should they be required in considering the implementation of regulations relating to the recreational utilization of the Nation's waters.

A. W. Breidenbach, Ph.D.
Director
National Environmental Research
Center, Cincinnati

ABSTRACT

The objective of this study was "to obtain sufficient laboratory and field data to be able to predict the number of outboard engines which can be operated on any particular body of water without causing adverse effects on the aquatic environment." To achieve this objective four small natural bodies of water were subjected to outboard engine emissions three times greater than saturation (maximum) levels occurring under "real world" boating conditions. These natural water bodies were stressed at these high levels with outboard engine exhaust emissions for a period of three years. The study showed that there were no "dramatic" or acute changes in the physical, chemical or biological characteristics of the water or sediments of the test lakes at these high stressing levels.

After three years of investigation no major adverse effects on water quality or the biological communities (periphyton, phytoplankton, zooplankton, benthos and fish) indigenous to the test lakes were observed under the study conditions.

No adverse accumulation of lead or hydrocarbons in the water column was observed. Also, no statistically significant accumulation of lead or hydrocarbons was noticed to be taking place in the lake sediments. Minor variations were observed in the periphyton community structure, which showed a shift to more heterotrophic associations under stress conditions. During one year, primary production of the phytoplankton community was lower under stress conditions; however over the three year study variations in primary production between stressed and non-stressed systems showed no statistically significant difference.

This report was submitted in fulfillment of Project Number 15020GPG and Grant Number R-801799 by the Boating Industry Associations under the partial sponsorship of the Environmental Protection Agency.

CONTENTS

Page

Abstract iv
List of Figures vi
List of Tables viii
Acknowledgements xii

Sections
I Conclusions 1
II Recommendations 4
III Introouduction 6
IV Methodology 20
  Chemistry 20
    Factors Studied and Sampling Frequency 20
    Methods of Field Collection 28
    Analytical Procedures 30
  Biology 36
    Factors Studied and Sampling Frequency 36
    Methods of Field Collection 37
    Analytical Procedures 43
V Results and Discussion 61
  Chemistry 61
    General Chemistry 61
    Heavy Metals - Lead and Cadmium in Water Column 69
    Heavy Metals - Lead and Cadmium in Sediments 74
    Hydrocarbons in Water Column 78
    Hydrocarbons in Sediments 82
  Biology 89
    Periphyton 89
    Species Proportional Counts 89
    Gravimetric Biomass, Chlorophyll, Autotrophic Index 91
    Phytoplankton 105
    Species Abundance and Occurrence 105
    Short Term Population Dynamics 141
    Primary Productivity 143
    Chlorophyll 146
    Productivity Index 152
    Photosynthetic Inhibition Around Engines 153
    Zooplankton 161
    Benthos 176
    Fish 190
VI References 193

LIST OF FIGURES

Number		Page
1	Northern Field Study - Test Facility	8
2	Simulated Motorboat Emission Loading Spatial Consideration - Lake Geneva, Wisconsin 1000 hours to 1800 hours	11
3	Simulated Motorboat Emission Loading Spatial Consideration - Lake Geneva, Wisconsin 0600 to 1000 hours and 1800 to 2000 hours	12
4	Stress Levels	15
5	Stations for Water and Sediment Chemistry Sampling	23
6	Liquid Chromatographic System for Fractionation of Hydrocarbon Material	34
7	Alphanumeric Grid Used to Locate Benthos Sampling Points	42
8	Resolution of C_{10}-C_{36} Even Numbered N-Paraffin Mixture	83
9	Periphyton Autotrophic Index - Ponds 1 and 2, 1972 & 1973	102
10	Periphyton Autotrophic Index - Ponds 3 and 4, 1972 & 1973	103
11	Phytoplankton Species Dynamics 1971	109
12	Phytoplankton Species Dynamics 1971	110
13	Phytoplankton Total Biomass 1971	111
14	Phytoplankton Total Biomass 1971	112
15	Phytoplankton Tychoplankton Biomass 1971	113
16	Phytoplankton Tychoplankton Biomass 1971	114
17	Phytoplankton Euplankton Biomass 1971	116
18	Phytoplankton Euplankton Biomass 1971	117
19	Total Phytoplankton Ponds 1 & 2, 1972-1973	120
20	Total Phytoplankton Ponds 3 & 4, 1972-1973	121
21	Dominant Phytoplankton Groups Ponds 1 & 2 1972-1973	122

LIST OF FIGURES

Number		Page
22	Dominant Phytoplankton Groups Ponds 3 & 4 1972-1973	123
23	Phytoplankton Richness 1972-1973	127
24	Phytoplankton Richness 1972-1973	128
25	Phytoplankton Similarity 1972-1973 Pond 1 vs. 2 and Pond 3 vs. 4	133
26	Phytoplankton Similarity 1972-1973 Pond 1 vs. 3 and Pond 2 vs. 4	134
27	Phytoplankton Chlorophyll *a* - 1973	149
28	Zooplankton Population Dynamics 1972 Pond 1 and Pond 2	165
29	Zooplankton Population Dynamics 1972 Pond 3 and Pond 4	166
30	Zooplankton Population Dynamics 1973 Pond 1 and Pond 2	172
31	Zooplankton Population Dynamics 1973 Pond 3 and Pond 4	173
32	1972 Versus 1973 Net-Zooplankton Numbers	174
33	1971 Benthic Macroinvertebrate Diversity	179
34	1971 Macroinvertebrate Biomass	180
35	$\bar{X}$ Macroinvertebrate Biomass 1972	182
36	Macroinvertebrate Biomass 1973	184
37	Macroinvertebrate Species Richness $(S\sqrt{}/N)$ 1973	185
38	Macroinvertebrate Richness Component $(S-1/1_nN)$ 1973	187

LIST OF TABLES

Number		Page
1	Stress Levels	18
2	Analytical Methods - Water Chemistry	31
3	Analytical Methods - Sediment Chemistry	32
4	Gas Chromatographic System for Boiling Point Characteristics	35
5	Fish Sampling Schedule	44
6	Chemical Statistics - Water Column Data	64
7	Lead in Water Column	70
8	Cadmium Levels in Water Column	72
9	Lead in Bottom Sediments	75
10	Cadmium in Bottom Sediments	76
11	Chemical Statistics - Sediment Data	77
12	Hydrocarbons (Boiling Point Range 175°-300°C)	84
13	Hydrocarbons in Water Column - Statistics	85
14	Hydrocarbons in Sediments	86
15	Hydrocarbons in Sediment - Statistics	88
16	Periphyton Similarity Within Ponds Sorensons Similarity Coefficient $\frac{2c}{a+b}$	90
17	Periphyton Richness (S-1/lnN)	92
18	Periphyton Production	93
19	Mean Organic Productions	98
20	Periphyton Autotrophic Index as Calculated From Mean Organic Biomass (mg/m^2) and Mean Chlorophyll a (mg/m^2)	100
21	Periphyton Statistics	101
22	Species and Occurrence of Phytoplankton-1971	106
23	Phytoplankton Species Richness Measurements	118
24	Incidential Data of Blue-Green Algal Bloom	126
25	Mean and Standard Deviation of Species Richness (S/$\sqrt{N}$)	126

LIST OF TABLES

Number		Page
26	Mean and Standard Deviation of Richness (S-1/lnN)	130
27	Phytoplankton Similarity Coefficients 1972-1973	131
28	Phytoplankton Similarity Coefficients Comparing Stress Ponds 1 and 3	132
29	Comparisons of Abundance of the 26 Major Phytoplankton Species	138
30	Phytoplankton Statistics	139
31	Mean Phytoplankton Productivity	144
32	Productivity of Stress Compared to Control Ponds	145
33	Phytoplankton Chlorophyll a and Productivity Index from Routine Collections	148
34	Test of Covariance - Chlorophyll a vs. Numbers of Individuals	151
35	Productivity Inhibition Around Engines	154
36	Productivity Around Engines - Cell Counts	154
37	Mean Cell Counts	155
38	Productivity Inhibition Around Engines Chlorophyll a	155
39	Productivity Inhibition Around Engines - Productivity Index	156
40	Mean Productivity Index	156
41	Correlation of Chlorophyll a (mg/m^3) to ^{14}Carbon Production	159
42	1972 Mean Percent Abundance of the Rotifera and Family Brachionidae	162
43	Population Dynamics of Net-Zooplankton Community - September 1972	164
44	Population Dynamics as Related to Net-Zooplankton Richness August 1972	168
45	Zooplankton Richness as Compared to Percent Taxa Increase	169
46	Mean Values of Sorenson's Similarity - Coefficient - Zooplankton Community (August to October 1972)	169

LIST OF TABLES

Number		Page
47	1973 Mean Percent Abundance of the Rotifera and Family Brachionidae	170
48	Dominant Zooplankton Species 1973	170
49	Zooplankton Statistics	177
50	Benthos Statistics	189
51	Wrong Choices by Taste Panel on Two Sets of Fish Samples	191

APPENDICES LIST

Number		Page
A1	Surface Area Stress Levels	202
A2	Surface Area Stress Levels-Yearly Basis	204
A3	Volume Stress Levels-Yearly Basis	205
B1	Engines Used During Test Period	206
B2	Stress Levels for Test Sections	207
B3	Fuel Analysis: Indolene Clear (Non-Leaded)	208
B4	Fuel Analysis: Indolene #30	209
B5	Trace Metals in Bottom Sediments	210
C1-C18	Physical and Chemical Analysis	211
C19	Periphyton Species List	230
C20	Phytoplankton Biomass	247
C21	Abundance of Dominant Phytoplankton Groups	252
C22	Phytoplankton Species List	256
C23	Total Zooplankton Organisms Per Haul (1972)	283
C24	1972 Zooplankton Richness and Similarity Coefficient Calculations	289
C25	Total Zooplankton Organisms Per Haul (1973)	292
C26	1973 Zooplankton Richness and Similarity Coefficient Calculations	297
C27	1971 Species Composition (Benthos)	299
C28	1971 Diversity Calculations	301
C29	1971 Biomass (Benthos)	303
C30	1972 Biomass and Species Composition (Benthos)	304
C31	1971 Diversity Calculations	305
C32	1973 Species Composition and Biomass (Benthos) 1972 Diversity Calculation (Benthos)	313
C33	Benthos - 1973 Diversity and Richness 1972 Richness Calculations	314
C34	Wrong Choices - Fish Taste Tests	315
C35	1973 Richness Calculation - Benthos	318
C36	1973 Diversity Calculations - Benthos	319
C37	Wrong Choices (As Percent of Total Possible) Compared to Volume of Fuel Used to Date	320

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SECTION I

CONCLUSIONS

1. No significant differences were seen in periphyton diatom richness and species distribution between ponds during two years of study.

2. Although variable, organic production was not significantly different nor was chlorophyll a production different between ponds. However, when placed in the ratio of the autotrophic index there was a significant difference between the control and non-leaded treatment sections during the 1972 sampling period. These differences, reflected by higher index values in the treatment section, indicate more hetertrophic (nonalgal) communities under outboard engine stress conditions. This trend remained in 1973 but was not statistically significant.

3. Short term phytoplankton variations in species associations between ponds were not significant. Species richness and population similarity never varied to a significant degree throughout the two year period. Phytoplankton species associations varied annually in a manner indicative of natural lake systems reflecting species pulse phenomena dictated by natural factors, species interactions, and species periodicity.

4. Phytoplankton productivity measured by ^{14}carbon fixation indicated lower photosythetic carbon production in both the non-leaded and leaded stress sections when compared to their respective control sections in most collections during 1971, 1972, and 1973. Of these differences, only the lower carbon production in the non-leaded stress section compared to its control during 1972 was significant. These differences cannot be directly attributed to natural population variations as species associations and richness were similar throughout the pond system during this study.

5. Chlorophyll a measurements of the phytoplankton recorded during 1973 showed no significant difference between the non-leaded test pond and its control pond. During the same period a significant difference was recorded in chlorophyll a measurements between the leaded stress pond and its adjacent control pond.

6. Phytoplankton productivity index values showed no photosynthetic inhibition in terms of a ratio of ^{14}carbon production to chlorophyll a. Although only a few data points were analyzed this index is felt to be legitimate and useful in studies of primary productivity.

7. A preliminary study in the immediate vicinity of the outboard test engines did not show significant effects on primary production when cell counts, chlorophyll a and ^{14}carbon production were compared before and after engine runs.

8. Zooplankton population dynamics, comparative species richness, abundance, and occurrance were indicative of normal temporal periodicity encountered in small temperate lakes. No effects on the zooplankton community can be attributed to the outboard motor emissions in the northern study system.

9. The benthic macroinvertebrate community demonstrated normal variations in population composition and dynamics. The 1972 shift in dominant organisms composing the benthic faunal assemblage was commensurate with the change in trophic structure of the ponds. There were no effects attributable to outboard motor usage in the ponds under study.

10. After two years of monitoring the various species of fish (Lepomis) for alterations in taste due to outboard motor operation in the test lakes, no tainting of the fish flesh was observed.

11. No major variation in the general water quality of the test ponds were observed after three years of stressing with two-cycle outboard engines.

12. No major variation in the major cations (calcium, magnesium, hydrogen ion) of the test sections was observed during the course of the study.

13. No major variation was observed in the major anionic species common to natural waters (chloride, carbonates, sulfate, and bromides).

14. No major variations in nitrogen (organic, ammonia, nitrite and nitrate) and total phosphorus or ortho-phosphate was noticed during this study.

15. No significant change in the concentration of saturated hydrocarbons with boiling points in the range of 175° to 300° (paraffins, naphthenes, mono- and di - olefins) in the water column was observed as a result of three years of outboard engine stressing.

16. No statistically significant (95 percent confidence level) buildup of saturated hydrocarbon was observed in the test ponds sediments after three years of engine operation. The data collected in this investigation cannot rule out the build-up of these materials in the sediments. The research data collected to date indicate that any increase in the saturated hydrocarbons present in the sediments involve saturates with carbon numbers C_{17} and above.

17. An increase in lead in the water column at the parts-per-billion level has been associated with stressing by outboard engines using leaded fuel. In hardwater lakes such as the Saline Michigan ponds, the concentration of lead in the water column is limited to the 10^{-7} M (about 20 ppb) range by one or more of the dissolved anions present. Consequently, the effect of stressing with leaded fuel is minimal.

18. The use of leaded fuel in outboard engines may increase the level of lead in the bottom sediments. Results from this study, though not conclusive, do indicate that this may be taking place in the leaded test section.

SECTION II

RECOMMENDATIONS

1. The effects of outboard marine engine exhausts on phytoplankton productivity is worthy of further investigation. The data have shown reduced ^{14}carbon fixation by the phytoplankton under the treatment conditions of non-leaded and leaded fuels, the former showing statistical significance. This phenomenon could be more closely observed under algal assay and continuous flow laboratory bioassay conditions where prepared media and natural waters are exposed to various levels of outboard engine treatment and fuels. Various growth rate and productivity measurements can be taken to relate carbon production on a per cell basis or per unit chlorophyll a̲ and expressed as a productivity index. Such expressions indicate phytosynthetic efficiency or inhibition, and under controlled assay conditions can be related directly to the stress variable being applied in the experiment.

2. Chemical analysis of the culture material should also be undertaken to determine hydrocarbon and heavy metal sorption or uptake by algal cells. These analyses could identify the exhaust fraction involved in photosynthetic inhibition if this is indeed a real phenomenon.

3. Experimental stressing of natural waters with outboard marine engines influenced the periphyton communities under study. Although no significant variations were seen in the species associations of the photoautotrophic organisms (diatoms), differences were seen in the production of organic biomass and chlorophyll a̲. When applied in a ratio as the autotrophic index the data reflected more hetertrophic periphyton communities under treatment conditions. The speculation being that there was greater microbial activity, i.e., bacteria and fungi, in the stress sections of the northern field study. Experimentation should be conducted to determine if this is the result of selective enrichment where the hydrocarbons of the exhaust emissions provide a carbon source for bacteria and fungi. This aspect should be studied under continuous flow bioassay conditions where natural water would be treated with outboard engine exhausts and fed through the bioassay system.

4. The zooplankton community demonstrated no effects observable at this level of study, i.e., gross population monitoring. It is felt then, that the zooplankton could be studied on a more individual manner, such as their robustness, fecundity and fertility. Gut analysis of the Rotifera, in a stressed situation, should also be undertaken to determine if the ratio of small alga (i.e., Chlorella sp.) to suspended detrital matter is concomitant with populations of unstressed lakes.

5. The benthic macroinvertebrates should be studied in light of their preferred habitat; the sediment. It should be determined, in a continuous flow bioassay unit using natural lake water as the diluent, if the population of Chironomidae demonstrate a reduced ability to exchange gases (O_2, CO_2 etc.) due to hydrocarbon build up. Biochemical analysis of the body tissues should then be performed to determine variations in lead, and the various hydrocarbons associated with the flesh of the organism. In the bioassay unit, the duration of the larval stage should also be determined. Species of macroinvertebrates less anatomically amorphous should also be observed and chemically analyzed on an anatomical basis; i.e., gills, body covering (chitin), and viscera. The icthyopopulation should be studied with particular reference to their gills and the possible build up of the heavy metals, and lead. A simple bioassay-animal dissection coupled with atomic absorption spectrophotometric determinations would yield information in this area.

6. There is some uncertainty concerning the build-up of lead in the bottom sediments as a result of outboard engine operation using leaded fuel. Consequently, further study should be made of the mechanisms of transport by which any significant concentration could occur, e.g. sedimentation. However, this potential environmental problem should be eliminated in the near future with the advent of non-leaded fuels and the development of two-cycle outboard engines capable of operating on such fuels.

7. The fate of hydrocarbons in the aquatic environment is still not well understood. The data presented in this report suggests the need for further study in the area. Such studies should focus on the physical, chemical and biological degradation of hydrocarbons in the aqueous and sediment phases as well as the mechanism of hydrocarbon transport between the two phases. This aspect should be looked at for "long-term effects". Probably, not as important per se for outboard motor emissions as much as aiding in ascertaining the environmental impacts of the total hydrocarbon input from man's activity on natural water systems.

SECTION III

INTRODUCTION

GENERAL

This report presents the major results and conclusions of a three year research project designed to ascertain the pollutional effect of two-cycle outboard engines on freshwater aquatic environments. The study was performed at the State of Michigan's Fisheries Research Station in Saline, Michigan. This research station is operated and maintained by the Department of Natural Resources, State of Michigan. This report represents the results from the northern field studies phase of EPA Grant Number R810799 and is one part of a three part study involving field studies in northern and southern environments and a laboratory study.

OBJECTIVE

The main objective of the study was:
To determine the effect of two-cycle outboard engine operation on the aquatic ecosystem. This includes not only determining whether any detrimental effects occurred, but also pinpointing that portion of the food chain which might be most seriously affected.

SCOPE OF WORK

The study was designed to evaluate the environmental impact of two cycle outboard motor emissions on the chemical and biological quality of natural lake systems. For this particular study, it was determined that laboratory scale studies would be inappropriate due to the inherent difficulties that would be associated with extrapolating the data to "real world" conditions. While studies of large lake systems were considered prohibitive from both an economic and time standpoint. Therefore, it was decided to perform the field studies on small, natural lake systems. This small or "mini" lake study concept allowed for the field investigations to be carried out on water bodies of manageable size. This approach also permitted simulation of the effects of long term stressing by two-cycle outboard engines to be accomplished over a relatively short period of time.

The field studies were conducted in two one-half acre (0.20 hectare) ponds located near Saline, Michigan. These ponds or "mini lakes" which have been in existence for over ten years, had no prior boating activity on them and received no other direct pollutional inputs other than the imposed stressing from two-cycle outboard engines operated under a predetermined schedule. Since this study dealt with the pollution impact of drainless two-cycle outboard engines using leaded and non-leaded fuels, each major pond was divided, by means of aluminum sheeting to provide two test ponds each with its own integral control section (Figure 1). Thus, one test pond was stressed by engines using leaded fuel while the other test pond was stressed by engines operating on non-leaded fuel.

The depths in the test and control ponds varied between four and nine feet (1.22 and 2.74 meters). Water levels in all ponds (test and control compartments) were controlled strictly by evaporation and rainfall. There were no natural surface or sub-surface water flows to the systems. Water level, hence water volume, was held constant by periodic water input when evaporation and seepage exceeded rainfall.

NORTHERN FIELD STUDY - TEST FACILITY

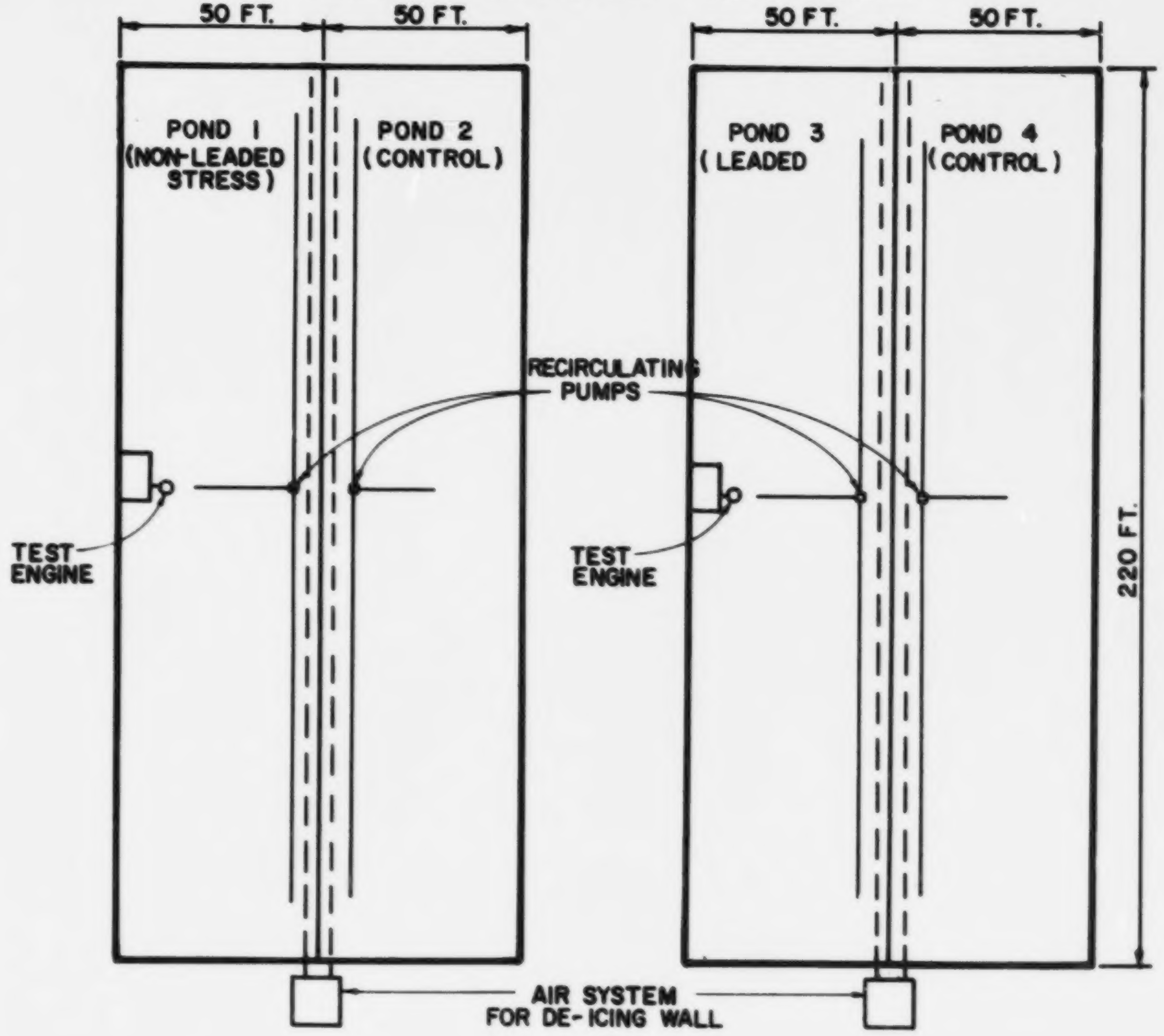

50 FT.
50 FT.
50 FT.
50 FT.
POND 1 (NON-LEADED STRESS)
POND 2 (CONTROL)
POND 3 (LEADED)
POND 4 (CONTROL)
RECIRCULATING PUMPS
TEST ENGINE
TEST ENGINE
220 FT.
AIR SYSTEM FOR DE-ICING WALL

FIGURE 1

STRESSING LEVELS

The first consideration in this study was to determine the amount of two-cycle outboard stressing that was to be applied to the test ponds. The amount of outboard stressing to be applied to each test system was approached by ascertaining, as closely as possible, the number of boats that reasonably could be expected to occupy a given surface area of water under optimum use condition. Optimum use conditions being a "real-world" situation where the following conditions exist:

- a) diversity of boating activity taking place
- b) lake surface large enough to have boats operating over a wide spectrum of horsepower loadings
- c) Lake should be at maximum usage capacity (saturation boating). Saturation boating being that situation where from a safety, aesthetic, and recreational viewpoint the presence of more boats on the lake would cause:
    1. a problem of boating safety
    2. reduce one of the legimate use activities presently taking place
    3. reduce the recreational attractiveness of the lake

A literature review was undertaken to determine the spatial (surface area) requirements per boat based on a specific boating activity. In 1967, Threinen[1] reported on his findings of boating activity on Lake Geneva, Wisconsin. A review of Threinen's work indicated that the boating situation on Lake Geneva during a peak holiday weekend period (July 4th) was at or near optimum. This boating situation (together with the size of Lake Geneva) satisfied all the necessary qualifications set forth previously for defining optimum use conditions.

Therefore, the work of Threinen on Lake Geneva, Wisconsin was used as the base to determine the level of outboard motor stressing that would be used in this study.

Schematic flow sheets of the instantaneous boat population and specific boating activities as developed from Threinen's work on Lake Geneva[1] are shown in Figures 2 and 3. Figure 2, which shows the average instantaneous boating activity from 1000 to 1800 hours, indicates that there is essentially total saturation with respect to motorboat usage during this period (i.e. 5100 acres of water available and if Threinen's recommended spatial requirements per boat activity are followed 5250 acres of water are needed for the boat population). Figure 3 shows the boating situation on Lake Geneva during Threinen's study on non-peak hours (0600 to 1000 and 1800 to 2000 hours).

A review of Figure 3 shows that although the boating population is identical to the population shown in Figure 2, Lake Geneva is nowhere near the saturation boating situation (5100 acres of water available with only 720 acres of water being used). The reason for this being that the majority of boats in the non-peak hours are engaged in fishing. This particular activity (fishing) requires the minimum amount of water surface area per boat (1 acre per boat).

It is of interest to note that Threinen's work[1], which is the basis for the stress levels employed in this study, approached the saturation boating situation from considerations of safety. The Lake Geneva study indicates that under diverse boating activity a recommended saftey level, as defined by Threinen, will be exceeded when there is more than one motor boat per 8.5 acres of water (5100 acres divided by 600 boats - see Figure 2). Another study by Ashton and Chubb[2] approached the saturation boating situation from a completely different per-

FIGURE 2

SIMULATED MOTORBOAT EMISSION LOADING

Spatial Consideration - Lake Geneva, Wisconsin

Peak weekend period (July 4, 1967)

1000 hours to 1800 hours

Lake Geneva

(5100 Acres of Water)
2064 hectares of Water

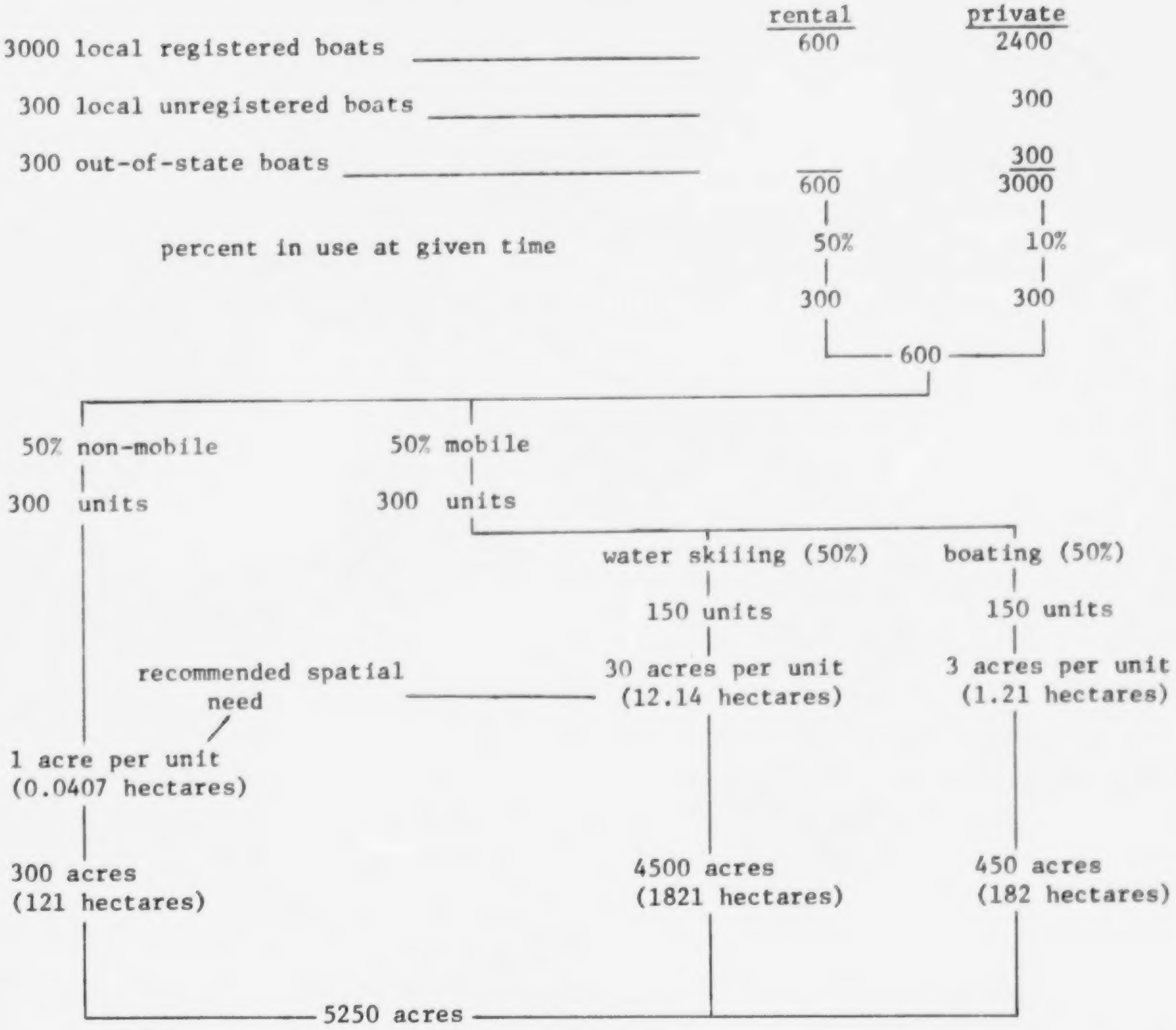

rental
private
3000 local registered boats
600
2400
300 local unregistered boats
300
300 out-of-state boats
300
600
3000
percent in use at given time
50%
10%
300
300
600
50% non-mobile
300 units
50% mobile
300 units
water skiing (50%)
150 units
boating (50%)
150 units
recommended spatial need
30 acres per unit (12.14 hectares)
3 acres per unit (1.21 hectares)
1 acre per unit (0.0407 hectares)
300 acres (121 hectares)
4500 acres (1821 hectares)
450 acres (182 hectares)
5250 acres

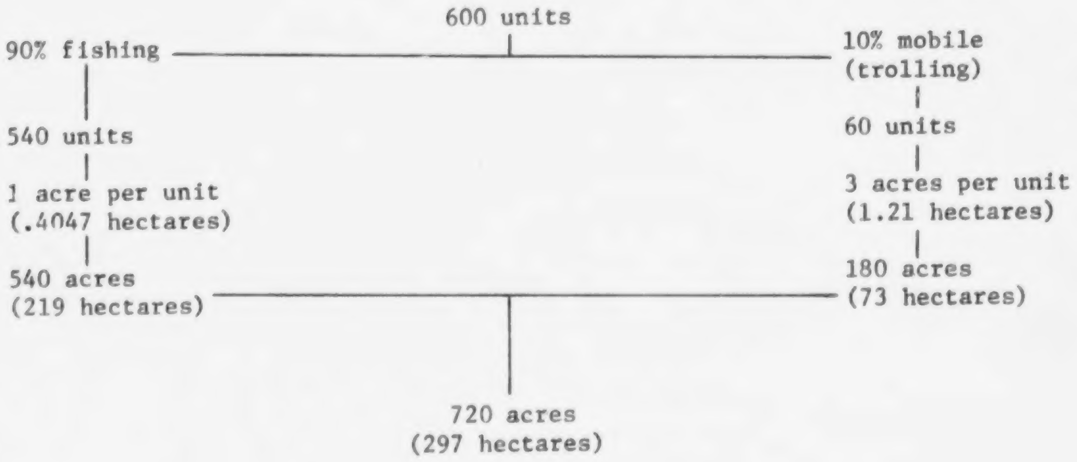
FIGURE 3

SIMULATED MOTORBOAT EMISSION LOADING

Spatial Consideration - Lake Geneva, Wisconsin

Peak Weekend - non-peak hours

0600 to 1000 hours and 1800 to 2000 hours


600 units
90% fishing
10% mobile (trolling)
540 units
60 units
1 acre per unit (.4047 hectares)
3 acres per unit (1.21 hectares)
540 acres (219 hectares)
180 acres (73 hectares)
720 acres (297 hectares)

spective. These investigators[2] surveyed three heavily used lakes in the vicinity of Detroit, Michigan to determine when usage conditions would cause boaters to seek a more favorable recreational site for their activities. These investigators found that when the usage activity exceeded one boat per 6 to 8 acres of water, boaters started to become disenchanted with the site and sought other less crowded lakes.

These two studies[1,2] point to the fact that boating safety and recreational attractiveness of a particular body of water are interrelated. More importantly, however, for the case at hand, these studies also verify that the boating situation upon which the stress levels for this study were based is indeed at saturation or maximum use conditions.

Using the data from Figures 2 and 3, and making the following assumptions for average brake horsepower (bhp) output for the various boating activities:

water skiing - 40 bhp
boating - 10 bhp
trolling - 5 bhp

a total brake horsepower input of 61,800 hours for the peak day at Lake Geneva was calculated (Appendix A1). Since an average of one gallon (3.785 liters) of fuel is consumed for 6 bhp-hours[3], this represents a daily fuel consumption of 10,300 gallons (38,986 liters), or approximately two gallons of fuel burned per acre per day (18.7 liters per hectare per day).

The vast majority of lakes do not receive such extensive boating usage on a daily basis. However, it was decided for the purpose of this study to assume that the maximum weekly stressing level of a hypothetical lake saturated by boating activity would be represented by two days of peak activity

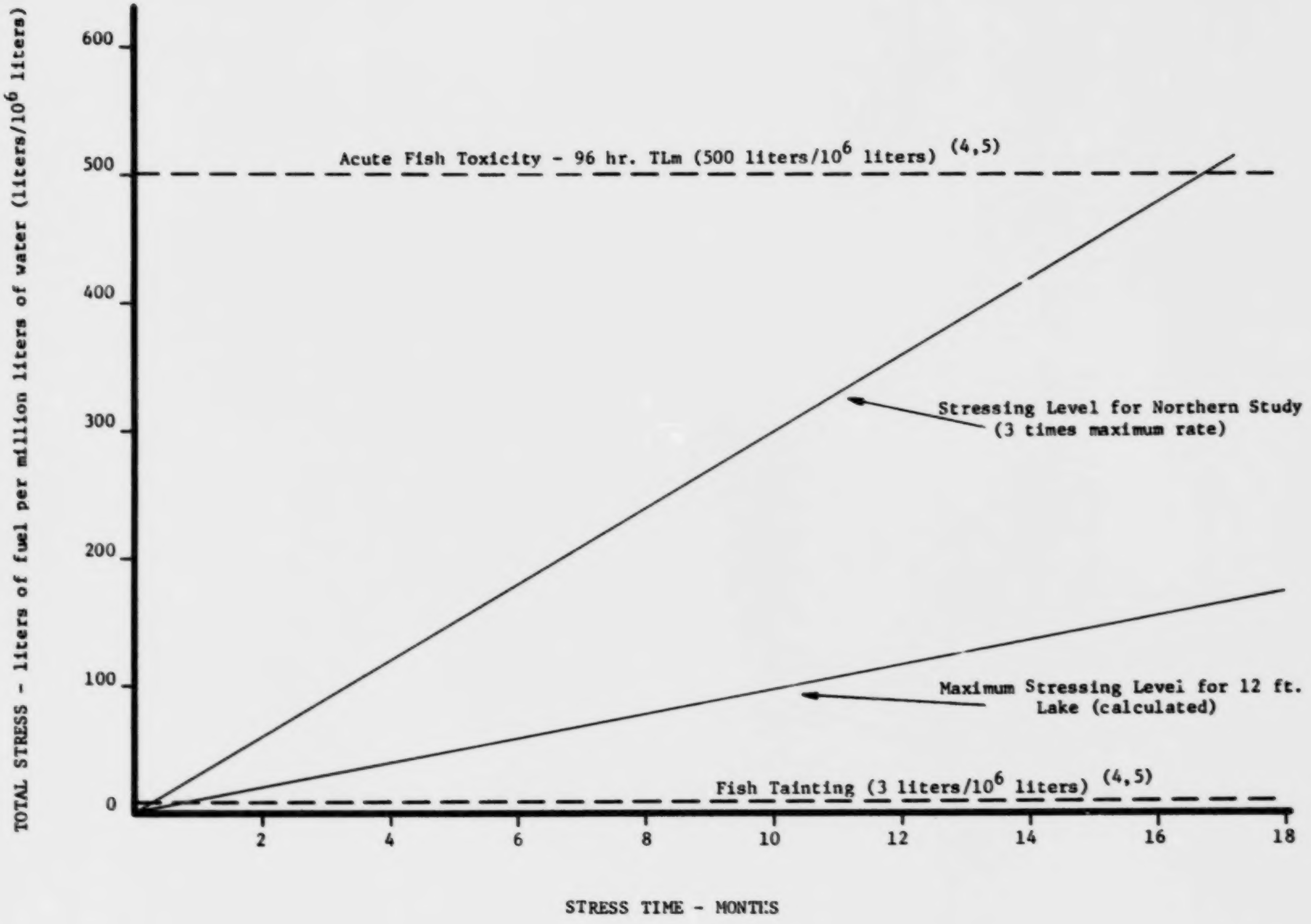
(18.7 liters per hectare per day) and five days of one-half peak activity (9.35 liters per hectare per day) of that shown for Lake Geneva. The total maximum weekly outboard motor stress, for a lake saturated by motorboat activity, was thus calculated to be nine gallons of fuel burned per acre (85.15 liters of fuel burned per hectare) (see Appendix A1). Finally, for this study, a boating season of eight months was assumed, while in reality the normal yearly boating season in the northern part of the United States is only four to five months in duration. This hypothetical eight month boating season yields a total yearly stress (see Appendix A2) of approximately 300 gallons of fuel burned per acre (2806 liters per hectare).

These calculations (yearly stress levels of 300 gallons of fuel burned per acre), however, provide no information as to the stressing levels in terms of water volume, since no restriction has been placed on the depth of the lake. Obviously, certain boating activities would be limited without sufficient water depth. A twelve foot (3.66 meters) average lake depth was assumed for purposes of placing the stressing level in terms of water volume. It was felt that this depth would be the minimum required for such non-restricted boating activity, and that a lake of this depth would most likely be the first to experience stress, if any, due to two-cycle outboard motor operation. The yearly stress - based on an eight month daily stress over an eight month boating period would then be approximately 0.33 liters of fuel burned per day per million liters of water.

This level of stressing is shown graphically in Figure 4. Also shown in this figure are the levels reported by English, et. al.[4,5] for fish tainting and acute fish toxicity of 3 and 500 liters of fuel burned per million liters of water, respectively. It is evident from the intersection of the stress line for

FIGURE 4

Design Stress Levels



a twelve foot (3.66 meters) lake with the reported toxicity levels[4,5] that the chances for observing effects from two-cycle outboard motor exhaust emissions would be minimal. Consequently, the calculated maximum stressing schedule established for this study was tripled. Thus, the stressing level used in the field studies for this project was approximately one liter of fuel burned per day per million liters of water - see Figure 4.

The engines used in the stressing were provided by the three major two-cycle outboard engine manufacturers, Outboard Marine Corporation, Mercury Marine Corporation and Chyrsler Corporation, from standard production models (see Appendix B1). Before use in the field each engine was "aged" by running the engine for approximately 50 hours which is equivalent to one year of normal operation[6]. The engines employed in the field studies over the three year test period ranged in size between 2 and 50 horsepower and were a mixture from the three manufacturers. The engines were rotated on a random basis over the three year test period. At no time during the three year period were any of the engines tuned or maintained.

In general, over a week stress period, the engines were operated at 1/4 speed (1000 to 1500 rpms) for 25 percent of the time and 3/4 speed (3000 rpms) for 75 percent of the time. The time and speed settings were agreeded upon values[7] used to represent normal boating operations. All engines used in the northern field study were of the drainless type.

After the ponds were divided, they were allowed to re-establish their normal flora and fauna for a period of ten (10) weeks prior to stressing by two-cycle outboard engines. Stressing began on September 22, 1971 at the northern test site at the rate of 1.2 gallons of fuel burned per pond per day. This is equivalent to a stress rate of approximately 2.4 gallons of fuel burned per million gallons per day which was higher than the stress rate used in the second and third year of the study (see Appendix B2). This higher level was necessary in order to bring the first year stressing in line with the agreeded upon stress schedule (Figure 4) because of the late start of the study the first year. Stressing for the first year was terminated on the first of December, 1971 due to the formation of ice on the ponds. The stressing schedule shown in Table 1 summarizes the total fuel inputs into both the leaded and non-leaded test sections and the engines used during the study.

The fuel utilized throughout the study was Indoline 30 for the leaded test section (this gasoline contains 3 grams of tetraethyl lead per gallons) and Indolene clear (no lead) for the non-leaded test section. Both of these gasolines are produced by the Standard Oil Corporation to rigid specifications and are commonly used in engine testing programs where constant fuel characteristics are deemed necessary (see Appendices B3 and B4). Standard two-cycle engine oil was added to the gasoline at the recommended ratio of one part oil to fifty parts gasoline (1:50).

TABLE I

STRESS LEVELS

A. Non-Leaded Test Section

Date	Engine	Stress Rate gallons burned per million gallons per day	Cummulative Stress Level gallons burned per million gallons
1971			
22 Sep - 4 Oct	2 Hp Evinrude	2.4	28.8
4 Oct - 18 Oct	4 Hp Mercury	2.4	62.4
18 Oct - 1 Nov	8 Hp Mercury	2.4	96.0
1 Nov - 15 Nov	4 Hp Mercury	2.4	129.6
15 Nov - 29 Nov	8 Hp Chrysler	2.4	163.2
29 Nov - 1 Dec	2 Hp Johnson	2.4	168.0
1972			
1 May - 6 May	8 Hp Chrysler	0.3	169.5
8 May - 13 May	18 Hp Evinrude	0.5	172.0
15 May - 20 May	35 Hp Chrysler	0.7	175.5
22 May - 27 May	4 Hp Mercury	1.0	180.5
27 May - 12 Jun	50 Hp Mercury	1.0	196.5
12 Jun - 26 Jun	2 Hp Johnson	1.0	210.5
26 Jun - 10 Jun	8 Hp Chrysler	1.0	224.5
10 Jul - 24 Jul	18 Hp Evinrude	1.0	238.5
24 Jul - 7 Aug	35 Hp Chrysler	1.0	252.5
7 Aug - 21 Aug	4 Hp Mercury	1.0	266.5
21 Aug - 4 Sep	50 Hp Mercury	1.0	280.5
4 Sep - 18 Sep	2 Hp Evinrude	1.0	294.5
18 Sep - 2 Oct	8 Hp Chrysler	1.0	308.5
2 Oct - 16 Oct	18 Hp Evinrude	1.0	322.5
16 Oct - 30 Oct	35 Hp Chrysler	1.0	336.5
30 Oct - 13 Nov	4 Hp Mercury	1.0	350.5
13 Nov - 27 Nov	50 Hp Mercury	1.0	364.5
27 Nov - 1 Dec	2 Hp Evinrude	1.0	368.5
1973			
15 May - 1 Jul	18 Hp Evinrude	1.0	421.0
1 Jul - 20 Aug	4 Hp Mercury	1.0	478.0

TABLE 1

STRESS LEVELS (continued)

B. Leaded Test Section

Date	Engine	Stress Rate gallons burned per million gallons per day	Cummulative Stress Level gallons burned per million gallons
1971			
22 Sep - 4 Oct	4 Hp Mercury	2.4	28.8
4 Oct - 18 Oct	2 Hp Evinrude	2.4	62.4
18 Oct - 1 Nov	4 Hp Mercury	2.4	96.0
1 Nov - 15 Nov	8 Hp Chrysler	2.4	129.6
15 Nov - 29 Nov	2 Hp Johnson	2.4	163.2
29 Nov - 1 Dec	8 Hp Chrysler	2.4	168.0
1972			
1 May - 6 May	8 Hp Chrysler	0.3	169.5
8 May - 13 May	18 Hp Evinrude	0.5	172.0
15 May - 20 May	35 Hp Chrysler	0.7	175.5
22 May - 27 May	4 Hp Mercury	1.0	180.5
27 May - 12 Jun	50 Hp Mercury	1.0	196.5
12 Jun - 26 Jun	2 Hp Evinrude	1.0	210.5
26 Jun - 10 Jul	8 Hp Chrysler	1.0	224.5
10 Jul - 24 Jul	18 Hp Evinrude	1.0	238.5
24 Jul - 7 Aug	35 Hp Chrysler	1.0	252.5
7 Aug - 21 Aug	4 Hp Mercury	1.0	266.5
21 Aug - 4 Sep	50 Hp Mercury	1.0	280.5
4 Sep - 18 Sep	2 Hp Evinrude	1.0	294.5
18 Sep - 2 Oct	8 Hp Chrysler	1.0	308.5
2 Oct - 16 Oct	18 Hp Evinrude	1.0	322.5
16 Oct - 30 Oct	35 Hp Chrysler	1.0	336.5
30 Oct - 13 Nov	4 Hp Mercury	1.0	350.5
13 Nov - 27 Nov	50 Hp Mercury	1.0	364.5
27 Nov - 1 Dec	2 Hp Evinrude	1.0	368.5
1973			
15 May - 1 Jul	35 Hp Chrysler	1.0	421.0
1 Jul - 20 Aug	8 Hp Chrysler	1.0	478.0

SECTION IV

METHODOLOGY

CHEMISTRY

A monitoring scheme was devised to provide information on the water quality and sediment characteristics of the experimental ponds. This information would also pin-point any chemical changes in the water and sediment systems resulting from outboard motor emissions and provide supportive data for the biological investigations.

Factors Studied and Sampling Frequency

The sampling and analytical schedule encompassed four basic groups of compounds:

a) Conservative components, including:
   Hardness
   Calcium
   Magnesium
   Chloride
   Bromide
   Sulfate
   Conductivity

b) Non-conservative components, including:
   pH
   Suspended solids
   Volatile suspended solids
   Turbidity
   Dissolved oxygen

Temperature
Alkalinity
Total phosphorus
Ortho phosphate
Ammonia nitrogen
Organic nitrogen
Nitrite nitrogen
Nitrate nitrogen

c) Trace metals, including:
Lead
Cadmium

d) Hydrocarbons, including:
Aromatics
Saturates
Paraffins

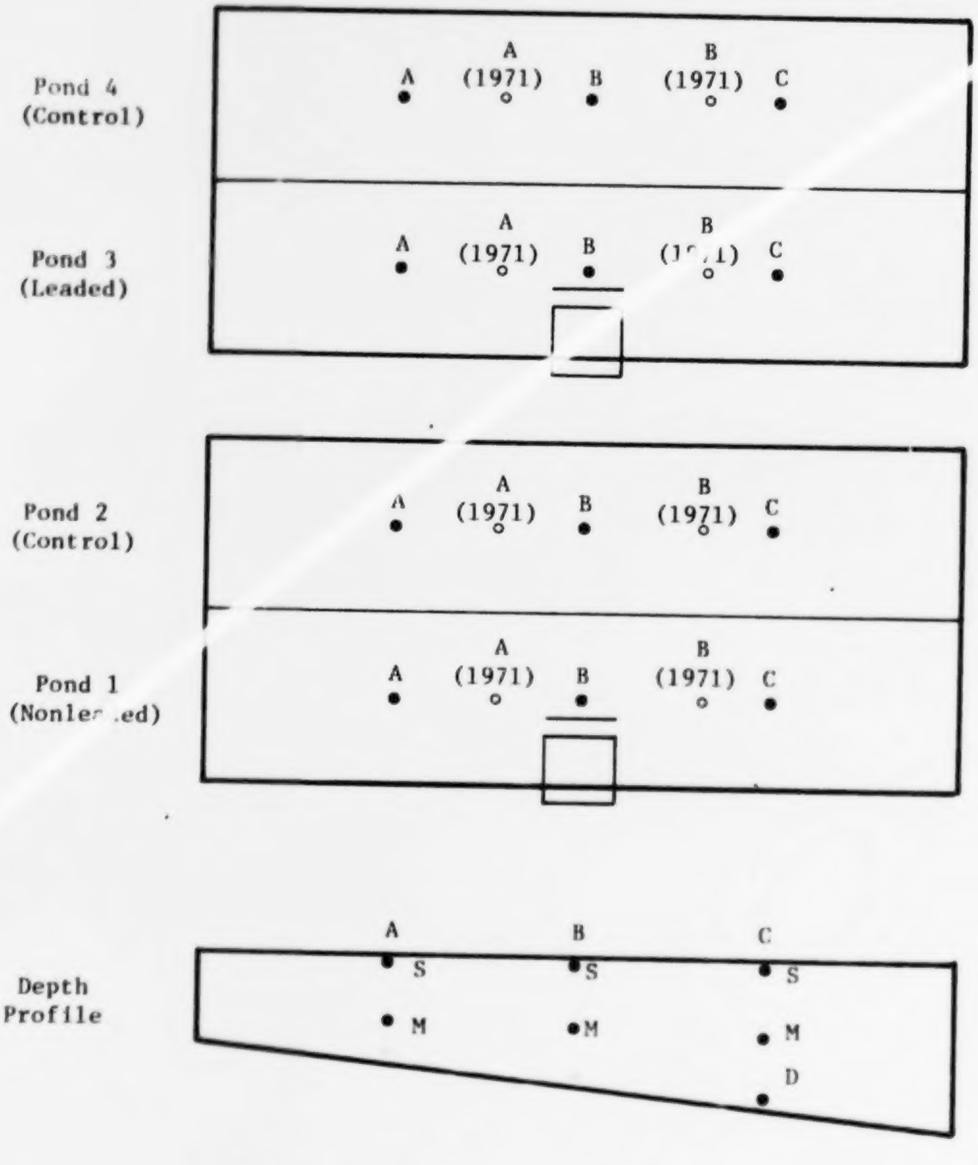
The arbitrary distinction between "conservative" and "non-conservative" components is made primarily to simplify the treatment of the chemical data. For purposes of this report, "conservative" components are those species which constitute a significant portion of the total dissolved solids and whose concentrations are not affected appreciably by the biological community. All other components are considered "non-conservative". Alkalinity, though present at relatively high concentrations in the "ponds"(100-200 mg/l as $CaCO_3$), serves as a primary source of carbon for biological growth and thus is considered a "non-conservative" component.

At different times in the study analysis of different groups was emphasized in an attempt to observe subtle changes resulting from outboard motor stressing. During the first stressing season (1971), the conservative and non-conservative components received major attention, as the study was geared to observe any acute changes in the lakes systems resulting from accelerated stress loadings. Fundamental changes in these two groups of components would constitute an important alteration of the general water quality and consequently would have an influential effect on the biological community. Sampling was performed on a weekly basis, with samples from two stations (A and B) being taken from each pond (Figure 5). Each sample was a composite of subsamples taken from three depths (surface, middle and near bottom). Sampling during the first year began one week before stressing commenced on September 22, 1971 and continued on a weekly basis until stressing was terminated. As a corollary investigation during this first stress season, samples of water, bottom sediment, and plant material were taken and analyzed for lead concentration. Preliminary work was also begun on adapting the analytical techniques for hydrocarbons in the water column developed in the University of Michigan laboratory studies for use in the northern field studies.

The stressing level for the 1972 season was set at 1 liter of fuel burned per million liters of water per day. Since no acute effects were observed during the first stress year, the chemical sampling and analyses program was modified in 1972. This modification involved more frequent sampling and more sophisticated analytical procedures. As during the first season, major attention was given to the conservative and non-conservative components. Calcium and magnesium were determined individually by atomic absorption. Chloride and bromide were determined much more precisely by ion selective electrodes to further define the variation in these substances seen during the first stressing season. Bromide was of some concern due to the use of ethylene dibromide as a scavenging agent in leaded fuel[8]. Conductivity was monitored near the end of the season in place of individual dissolved species as the focus of the chemical investigations shifted to the heavy metals and hydrocarbons. Virtually all of the non-

Figure 5

Stations for Water and Sediment Chemistry Sampling



Pond 4 (Control)
A
A (1971)
B
B (1971)
C
Pond 3 (Leaded)
Pond 2 (Control)
Pond 1 (Nonleaded)
Depth Profile
S
M
D

KEY

S - 15 cm below water surface

M - 100 cm below water surface

D - 25 cm from bottom

conservative components received increased attention in the form of improved analytical techniques and more rigorous sampling. Dissolved oxygen and temperature were monitored to observe the trophic state of the "mini-lakes". Hydrogen ion concentration and alkalinity, as well as nitrogen and phosphorus levels, were determined to provide correlation between nutrient sources and phytoplankton populations. Phosphorus concentrations in the water column were analyzed to the parts per billion range in order that minute inputs of this limiting nutrient could be observed.

In addition to the conservative and non-conservative components, the trace metals lead and cadmium were monitored in the water column on a routine basis during the 1972 season. Concern over lead levels stem from the highly toxic nature of this trace metal[9]. Virtually all life forms are vulnerable to lead toxicity in some way or another and biomagnification further complicates the problem. The intent of these weekly surveys was to observe the addition of lead, derived from the combustion of leaded fuel, to the water column. Theoretically, the level of this heavy metal would increase to the point where its solubility was limited by the carbonate and/or sulfate concentration. Further addition of lead to the water column would result in the formation of an insoluble salt which would exist in the collodial or particulate state. These particulates would ultimately find their way to the pond bottom through sedimentation causing an increase in lead concentration in the pond sediments. Cadmium was also monitored during the same period. Since there is a high degree of correlation between lead and cadmium in the soils surrounding the ponds (Appendix B5) and lead and cadmium have similar water chemistries, cadmium levels could possibly provide information on lead inputs resulting from runoff and peturbation of the bottom sediments. Near the end of the

1972 stressing season, samples of the sediments were taken with a Ponar dredge sampler and analyzed for lead to observe any increase in concentration of this trace metal in the bottom material of the ponds. Cadmium was also measured in these sediments to provide more insight into any changes in the natural background level of lead through association and correlation analysis.

Throughout the 1972 stressing season, attempts were made to trace the path of emission-derived hydrocarbon material into the ecosystems of the test ponds. The importance of assessing the impact of the various hydrocarbons added to the test pond systems cannot be overestimated. These compounds vary greatly in toxicity, solubility, and reactivity and consequently have a potentially widespread influence on an aquatic ecosystem. Aromatic hydrocarbons are acknowledged as the most toxic of this group of compounds. Low molecular weight aromatics are detrimental to both lower and higher order life forms. Their action on cell tissue includes disruption of fatty molecules as well as break-up of lipoprotein layers[10]. Some aromatic hydrocarbons, particularly the polycyclic aromatics, are known carcinogens[11]. For these reasons, initial emphasis was placed on determinations of aromatic hydrocarbons in the aqueous systems. Ultraviolet spectroscopy was the main tool for this work during the 1972 season.

Aliphatic and olefinic hydrocarbon compounds entering the water column also drew attention toward the end of the 1972 stressing season. These compounds lack the extreme toxicity of their aromatic counterparts and are appreciably degraded by microorganisms under aerobic conditions. However, since their solubility in aqueous solution is very limited, aliphatic and olefinic compounds are generally found as fine emulsions or they are adsorbed on associated particulates. When those particulates are microorganisms, such as phytoplankton, this sorption may interfere with cell functions. In such a sorbed state, these compounds (aliphatic and olefinic hydrocarbons) of relatively low chemical reactivity can be transported to the bottom sediments where cold temperatures and anerobic conditions dictate entirely different degradation processes. Some evidence indicates that anaerobic decomposition of these saturated species does take place, but at much lower rates than aerobic degradation[12,13]. In addition, further evidence suggests that the metabolities of anaerobic decomposition may be toxic to higher life forms[12]. To observe any changes in the level of saturates in the water columns of the stressed ponds, a quantitative infrared spectrophotometric procedures was used. These investigations were initiated during the final three months of stressing in 1972.

Sampling during the 1972 season was performed on a weekly basis. One sample from each pond was composited from subsamples taken at two depths in the western end of the pond (Stations A-S and A-M), two depths from the center of the pond (Stations B-S and B-M), and three depths from the deeper eastern end of the pond (Stations C-S, C-M and C-D) (Figure 5). This sampling frequency was continued until September when more attention was diverted to sediment chemistry. For the remainder of the season, the sampling for water chemistry was performed on a monthly basis.

Sediment samples for heavy metal analysis were taken monthly during October and November 1972 with a Ponar dredge sampler. In addition to lead and cadmium, the sample taken from each pond during November was analyzed for the trace metals chromium, copper, iron, manganese, nickel and zinc to better characterize the chemistry of the sediments underlying the test ponds.

The third season of stressing, 1973, utilized the same stress rates as 1972. The chemical investigations were expanded to provide information on sulfates and suspended particulate matter not previously studied. The conservative components were surveyed on a monthly basis utilizing the same techniques employed during the 1972 season. Sulfate was added to the list of parameters to aid in interpreting the heavy metal data. The non-conservative list of parameters was expanded to include information on the suspended particulate matter. Total suspended solids were measured to indicate the sorption potential for hydrocarbon species. Volatile suspended solids were monitored to provide supportive data for biomass and chlorophyll determinations. The trace metals lead and cadmium were sampled in the water column on a two to four week schedule. Sediment samples taken monthly with a coring device were analyzed for these two heavy metals. Additional trace metal analysis (chromium, copper and zinc) was performed on the July sediment samples (Appendix B5).

The sampling frequency for conservative and non-conservative components in 1973 was reduced to a monthly schedule from the weekly sampling undertaken in 1972. Such a reduced schedule provided sufficient data on general water chemistry to correlate the results from the third year of stressing with those of the previous two, and at the same time allowed more attention to be focused on trace metals and hydrocarbons analyses. The procedure for water sampling and sample compositing adopted for the 1972 stressing season was also utilized during 1973. Sampling for aqueous hydrocarbon and suspended solids analysis was performed on a two to four week schedule.

The greatest change in the 1973 survey schedule was the attention given to the potential hydrocarbon contributions to the aquatic ecosystem. A great controversy has developed the fate of petroleum derived hydrocarbons in the environment[12,14,15,16]. Most researchers, though not all, agree that hydrocarbons of the type comprising petroleum - paraffins, napthenes, olefins and aromatics - are found naturally occurring in areas untouched by petroleum pollution[13,16,17,18, 19, 20]. Precisely how these materials were derived is not understood, although the biogenesis of petroleum is a widely accepted theory. As mentioned earlier, some information on the aquatic chemistry of hydrocarbon compounds is available[12]. However, precisely what happens to such substances when they are released into an aquatic system is not completely understood. To provide information in this area, a new analytical method was utilized and applied to both water and sediment samples taken from the ponds during the 1973 stressing season. Hydrocarbon materials extracted from both types of samples were fractionated by chemical type utilizing elution chromatography on dual-packed silica gel-alumina adsorption columns. Further characterization by molecular weight was accomplished through analytical distillation by gas chromatography. Water samples for hydrocarbon analysis were taken on a two to four week schedule. Sediment samples were taken monthly using a hand coring device rather than a Ponar dredge sampler.

Methods of Field Collections

Throughout the three stressing seasons, field sampling for conservative and non-conservative components in the water column involved lowering a two liter nonmetallic Van Dorn bottle from a boat to a prescribed depth and triggering the device with a weighted messenger. Perturbation of the bottom sediments was avoided by careful measurement of depth. Water samples were composited in the field and transported to the laboratory and were refrigerated at 4°C. Analyses for unstable components (e.g. phosphorus, nitrogen, hydrocarbons, etc.) were begun immediately after field collection. Dissolved oxygen, temperature and conductivity were measured *insitu* utilizing portable sensing devices. Water samples for heavy metal analysis were stored in linear-polyethylene containers and preserved with 5 ml of concentrated nitric acid. Aqueous samples for hydrocarbon analysis were extracted with the appropriate solvent depending on the analytical method employed immediately upon receipt at the laboratory.

Sediment samples taken during 1971 and 1972 were collected with a 23 cm x 23 cm Ponar dredge. A 45 cm x 5 cm I.D. hand corer (Wildlife Supply Company, Saginaw, Michigan) was used to obtain all sediment samples in 1973. The use of a coring device allowed recovery and isolation of the top 5 cm of sediments. This upper layer is considered the most active both biologically and chemically since in highly organic sediments it generally includes the aerobic-anaerobic interface. Sediments from previous seasons (1971 and 1972) were a mixture of this upper layer and deeper material due to the sampling device employed (Ponar dredge). Sediment samples were frozen until analysis could begin. No attempt was made to fractionate the sediment by particle size, with the exception that small stones larger than 5 mm in diameter were manually excluded.

A diagram of the water and sediment sampling stations used in the chemical investigations is contained in Figure 5. It should be noted that the stations in 1971 are somewhat different than those used during the remainder of the study.

Analytical Procedures

A summary of the analytical methods employed during this study are contained in Tables 2 and 3. As noted earlier, many changes in analytical procedures were instituted between the 1971 and 1972 stressing seasons. These changes were made to provide increase sensitivity, precisions and accuracy in the analysis of chemical components. The sensitivity value quoted in Tables 2 and 3 is not in most cases the minimum detectable quantity, but rather the useful lower limit of the method taking into account all the preparative steps and the volume of sample used.

Although several of the procedures listed in Tables 2 and 3, such as the APDC-MIBK technique for lead and cadmium, the gas sensing technique for ammonia-nitrogen, and the procedures for aromatic and saturated hydrocarbons, are relatively innovative and are not characterized as standard methods[21, 22, 23]. They have been described in the references listed (Tables 2 and 3) and consequently will not be discussed here. The analytical method used for paraffinic hydrocarbons in 1973 is, however, worthy of discussion in this report.

The identification and quantification of hydrocarbon materials in a natural system is complicated by the fact that many organic molecules present in such a system resemble "true" hydrocarbons in both chemical and physical properties. Indeed it is felt that through hydrogenation or dehydrogenation, and partial fragmentation, such biologically derived materials can be transformed to the hydrocarbons constituting petroleum[24]. Consequently an anlytical method such as the carbon tetrachloride extraction - infrared absorption procedure listed in Table 2 provides data of limited value due to its inherently limited selectivity.

Table 2. ANALYTICAL METHODS - WATER CHEMISTRY

Component	Method	Year Used	Sensitivity	Reference
Hardness	EDTA titration	1971	2 mg/1	21
Hardness	Atomic absorption	1972-73	1 mg/1	25
Calcium	Atomic absorption	1972-73	1 mg/1	25
Magnesium	Atomic absorption	1972-73	0.1 mg/1	25
Chloride	Mercuric nitrate titration	1971	1 mg/1	21
Chloride	Ion selective electrode	1972-73	1 mg/1	26
Bromide	Phenol red reaction	1971	0.1 mg/1	21
Bromide	Ion selective electrode	1972-73	0.01 mg/1	27
Sulfate	Barium reaction - turbidity	1973	1 mg/1	21
Conductivity	Platinum electrode-Spec. Cond.	1972	5 μmhos	21
pH	Glass electrode	1971	0.1 units	21
pH	Glass electrode	1972-73	0.01 units	21
Suspended Solids	Glass filter mat	1973	0.1 mg/1	21
Volatile Suspended Solids	Glass filter mat	1973	0.1 mg/1	21
Turbidity	Hach turbidimeter	1972	0.1 Jackson Unit	22
Dissolved Oxygen	Polarographic electrode	1971-72	0.1 mg/1	21
Temperature	Thermistor	1971-72	0.5 °C	21
Alkalinity	Acid titration	1971-73	1 mg/1	21
Total Phosphorus	Persulfate digestion-Ascorbid Acid	1971-73	0.005 mg/1	21
Ortho Phosphate	Direct ascorbic acid	1971-73	0.005 mg/1	21
Ammonia Nitrogen	Distillation-Boric acid titration	1971	0.05 mg/1	21
Ammonia Nitrogen	Gas sensing electrode	1972-73	0.005 mg/1	28
Organic Nitrogen	Kjeldahl digestion-Boric acid titration	1971	0.1 mg/1	21
Organic Nitrogen	Kjeldahl digestion-Gas sensing electrode	1972-73	0.01 mg/1	28
Nitrite Nitrogen	Sulfanilic acid reaction	1971-73	0.001 mg/1	21
Nitrate Nitrogen	Brucine reaction	1971	0.1 mg/1	21
Nitrate Nitrogen	Ultraviolet absorption	1972-73	0.01 mg/1	21
Lead	APDC/MIBK - Atomic absorption	1972-73	0.4 μg/1	22, 28
Cadmium	APDC/MIBK - Atomic absorption	1972-73	0.1 μg/1	22, 28
Aromatic Hydrocarbons	Cyclohexane extraction - UV absorption	1972	0.01 mg/1	28
Saturated Hydrocarbons	Carbon tetrachloride extraction IR absorption	1972	0.5 mg/1	28, 29
Paraffinic Hydrocarbons	Carbon tetrachloride extraction LC-GC	1973	0.01 mg/1	(*)

*

Table 3. ANALYTICAL METHODS - SEDIMENT CHEMISTRY

Component	Method	Year Used	Sensitivity	Reference
Lead	Digestion - Atomic absorption	1972-73	1 mg/kg	30
Cadmium	Digestion - Atomic absorption	1972-73	0.1 mg/kg	30
Chromium	Digestion - Atomic absorption	1972-73	1 mg/kg	30
Copper	Digestion - Atmoic absorption	1972-73	0.1 mg/kg	30
Iron	Digestion - Atomic absorption	1972	10 mg/kg	25, 30
Manganese	Digestion - Atomic absorption	1972	10 mg/kg	30
Nickel	Digestion - Atomic absorption	1972	1 mg/kg	30
Zinc	Digestion - Atomic absorption	1972-73	1 mg/kg	30
Paraffinic Hydrocarbons	Soxhlet extraction - LC - GC	1973	0.1 mg/kg	(*)

* See text this report

To observe the effect of hydrocarbon emissions from outboard engines in the aquatic ecosystem, one must be able to isolate these substances from the large background of other naturally occurring organic material. A great wealth of information exists on the use of liquid chromatography on silica gel for this purpose[31-39]. An elution chromatography procedure was chosen for this study due to its compatability with gas chromatographic analysis of the fractionated hydrocarbons. A dual-packed system of silica gel and alumina adsorbents was used to fractionate the more polar species anticipated in samples from the test ponds. This system is essentially that developed in the American Petroleum Institute Research Project 60[40, 41]. A diagram of the chromatographic system is contained in Figure 6. This system separates the extracted organic material into four groups: saturates, monoaromatics, diaromatics and polyaromatics/polar compounds. The saturate fraction consists primarily of paraffins and naphthenes but mono- and di- olefins are also eluted with the saturates. The carbon tetrachloride extract, whether from an aqueous or sediment sample, is evaporated on activated silica gel to remove the solvent. This silica gel is then added to the top of the adsorbent column and the elution process is commenced.

Once the saturate hydrocarbon fraction has been isolated, it is subjected to analytical distillation by gas chromatography to determine approximate molecular weight distribution[42-44]. Three boiling ranges are resolved: range (a) 175°C - 300°C; range (b) 300°C - 400°C; range (c) 400°C - 530°C. Corresponding to molecules of (a) C_{10} - C_{16}; (b) C_{17} - C_{24}; (c) C_{25} - C_{40} respectively. Virtually all of the hydrocarbon emissions condensable in the aqueous phase are included and separated by the gas chromatographic system described in Table 4.

FIGURE 6

Liquid Chromatographic System for Fractionation of Hydrocarbon Material

Column ID 1.5 cm

ELUENTS

Prewet with Pentane
1st Fraction: 50 ml Pentane
2nd Fraction: 60 ml 5% Benzene in Pentane
3rd Fraction: 60 ml 15% Benzene in Pentane
4th Fraction: 10 ml 20% Benzene 20% Ethyl Ether in Methanol followed by: 20 ml Methanol

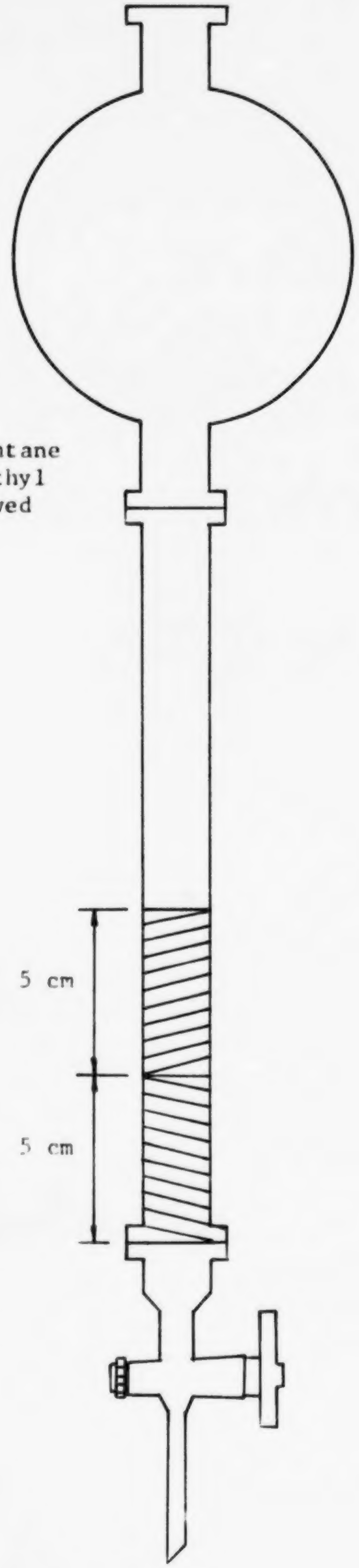

Silica Gel
100/200 Mesh
(Davison Grade 12)
Activated 24 hrs. @ 550°C
5 cm
Neutral Alumina
80/100 Mesh
(Chromatography Grade)
Activated 24 hrs. @ 550°C
5 cm

TABLE 4

GAS CHROMATOGRAPHIC SYSTEM FOR BOILING POINT CHARACTERIZATION

Instrument:	Varian 1860
Detector:	Flame ionization
Injection:	On column
Column:	
Length:	180 cm
O.D.:	3 mm
Coating:	SE - 30
Weight percent:	5
Support:	High performance Chromosorb W
Mesh:	80/100
Carrier gas:	Prepurified nitrogen
Rate:	50 ml/minute
Sample Size:	4 μl
Injector temperature:	305°C
Detector temperature:	325°C
Column temperature program:	
Preprogram:	1.5 minutes at 45°C
Program:	15°C per minute
Postprogram:	3.0 minutes at 250°C

BIOLOGY

Several biological communities were examined during the three year duration of the study. Various indices were applied to the data collected on these communities which aided in the interpretation of any changes within the various biological communities. Some of these indices were applied to the data from all communities while others were more specific and used on the data of a particular community. The data collected from these communities were tested for statistical significance of observed variations and related to the succession and cyclic phenomena of natural populations and to stressing levels of outboard engine exhaust emissions.

Factors Studied and Sampling Frequency

The biological communities sampled and the parameters studied were as follows:

Periphyton - Periphyton collections were taken during the 1972-1973 sampling periods on a monthly basis. This community was analyzed by the use of species proportional counts, gravimetric biomass, chlorophyll, and autotrophic index measurements. Species richness and similarity coefficients were used to determine the development and similarity of species associations within and between test-ponds.

Phytoplankton - Species abundance and occurrence were studied in 1971, 1972, and 1973; samples were collected twice weekly. Dominant species and biomass were examined in 1971 while dominant species and groups, species richness, and population similarity were examined in 1972-1973. During 1972, short term population variations were studied over a five day period. Primary productivity was measured by ^{14}carbon fixation during 1971-1973. Chlorophyll was measured during 1973 and related to ^{14}carbon production as a productivity index. A special experiment (1973) was designed to study the immediate effects of outboard engines on phytoplankton in the vicinity of the test-engine docks. In this experiment cell counts, chlorophyll, and ^{14}carbon production were compared.

Zooplankton - To aid in the assessment of the ecosystem under study, evaluation of the zooplankton community was added to the study in August 1972. Samples were collected twice weekly during 1972 and twice monthly during 1973. Species were identified and enumerated and the community analyzed in terms of species richness, population similarity, dominant species, and dominant taxonomic groups of species.

Benthos - The animals comprising the benthic macroinvertebrate community are directly subjected to adverse conditions by virtue of their preferred habitat and their general inability to move great distances by self locomotion. The benthic community is often a prime candidate of study in most water quality surveys. Both qualitative and quantitative benthos sampling and analysis were conducted during the three year duration of the study. Qualitative samples were collected in 1971 to determine variations of species distribution within and between test-ponds. Quantitative benthos measurements were taken each year (1971-1973), as was biomass. Species richness and population similarity was likewise determined.

Fish - Flesh taint tests were conducted in 1971 and 1972. Fish were caught by angling from the open waters in 1971 and prepared for taste tests. Live box taint experiments were carried out in 1972 where reared fish were placed inside an enclosure within each test-pond. These fish were caught by seining and taken to the laboratory for analysis.

Methods of Field Collection

Periphyton - Aritifical substrates[45, 46], were used to sample the periphyton community of the test ponds during

1972 and 1973. Standard size glass microscope slides, 25 mm wide x 75 mm long x 1 mm thick, were fastened to a supporting device which held them submerged at a depth of 10 cm to 15 cm for a specified period of time. Slides were fastened in a horizontal position to the surface of concrete building blocks[21, 47], and submerged near the banks in the test ponds during 1972. Collections from 1972 were also made from slides held in a vertical position in open, metal, tissue-staining trays. These trays were supsended from styrofoam floats anchored near the banks in the test ponds. No comparisons were drawn between these techniques but slides were suspended in the open water during 1973 to reduce the possibility of shading. During this period slides were supported to a vertical position in metal slide trays which were suspended in the center of 40-inch circumference hoops constructed with 1/2 inch diameter plastic pipe. These hoops, which provided sufficient floatation with minimum shading, were fastened to metal stakes in the open water of the test ponds. The floatation hoops had free rotation around the anchoring posts. Collections were taken from opposite ends of the test ponds; shallow water and deep water zones.

Slides, which were cleaned with dichromate cleaning solution and rinsed with distilled water prior to being planted in the test ponds, were permitted to incubate for periods of 14-30 days. Slides were visually observed daily at the sampling locations and were collected when growth appeared to be at a maximum state before material began sloughing from the artificial substrates[47]. At the time of collection, replicate slides from each station were taken for species identifications, gravimetric biomass determinations, and pigment extraction. Three ounce bottles were filled with preservative or extraction solvent and taken to the field where slides were lifted from the slide trays and placed in the bottles. Qualitative and gravimetric biomass samples were preserved with Transeau's solution, a mixture of six parts distilled water, three parts alcohol, and one part formalin, while those for pigment extraction were placed in a solvent solution of 90 percent acetone: 10 percent ethanol. All samples were placed in a dark styrofoam ice chest or taken immediately to the lab and placed in cold, dark storage.

Phytoplankton - Phytoplankton community evaluations were conducted as follows:

Routine phytoplankton collections - An opaque, horizontal, 2.1 liter VanDorn water sampling bottle was used to collect surface and submerged (1 meter) samples from the test ponds. Collections were made from opposite ends of the ponds (shallow and deep water) and from the middle area. At each site three sample bottle volumes were collected and emptied into large plastic containers yielding independent composite collections of surface samples and submerged samples. Collections were made twice each week. After thoroughly mixing the composite collections, replicate subsamples were removed for species identification and enumeration, ^{14}carbon productivity incubation, and pigment extraction.

Photosynthetic inhibition around engines - In this experiment the immediate effects of outboard engine exhaust emissions were investigated in terms of the photosynthetic index, i.e., photosynthetic efficiency. Composite surface samples were collected from four areas around the test engine dock. Likewise a depth composite was collected from a fixed position of five feet behind the test engine at a depth of two feet. Each composite consisted of four plastic bucket volumes (8 liters each) collected with a rubber diaphragm hand pump. Collections were made before engine-runs, after engine-run times of 30-35 minutes, and from the cooling water after 30 minutes running. Subsamples were removed from the composite collections and measured for chlorophyll a, ^{14}carbon fixation, and total cell numbers in the initial experiment. It was felt that the effects of hydrocarbon in exhaust emissions could be seen in the photosynthetic index, mg C fixed/hr./mg Chl. a[48].

Zooplankton - No single sampling method can accurately sample the entire zooplankton community due to the great diversity of individual size, selective vertical distribution, and the ability of the organisms to move both vertically and horizontally in the water colum [47, 49, 50]. The "Wisconsin" style plankton net and the net tow cast method was selected as the collecting procedure[47]. The ratio of the net mouth opening to the length of the filtering area (effective net length) of this net is about 1.5:7.0. The plankton net was towed at a constant speed the entire length of each test pond (≈ 67 meters); each net tow was then designated as a "haul". Due to the sampling procdure selected, no attempt was made to calculate the actual volume of water that passed through the net, consequently zooplankton numbers cannot be reported as numbers/unit water volume. They are reported as relative numbers per haul. The plankton net, upon retrieval, was immediately washed with tap water to concentrate the zooplankton in the removeable bucket. This concentrated sample was then washed from the bucket into a sample container containing a 4 percent formalin in saturated sugar solution for subsequent identification and enumeration in the laboratory.

Benthos - Prior to stressing, a qualitative benthic survey was performed using a long handled dip net. This was done to establish the taxa of infauna in the ponds and yielded a "pre-treatment" baseline of the natural benthic population. After numerous surveys through the macrophytes and substrate, sampling all possible habitat, the contents of the net were washed and emptied into a white enamel pan. The animals were hand picked and put into sample vials containing 70 percent ethyl alcohol for later identification.

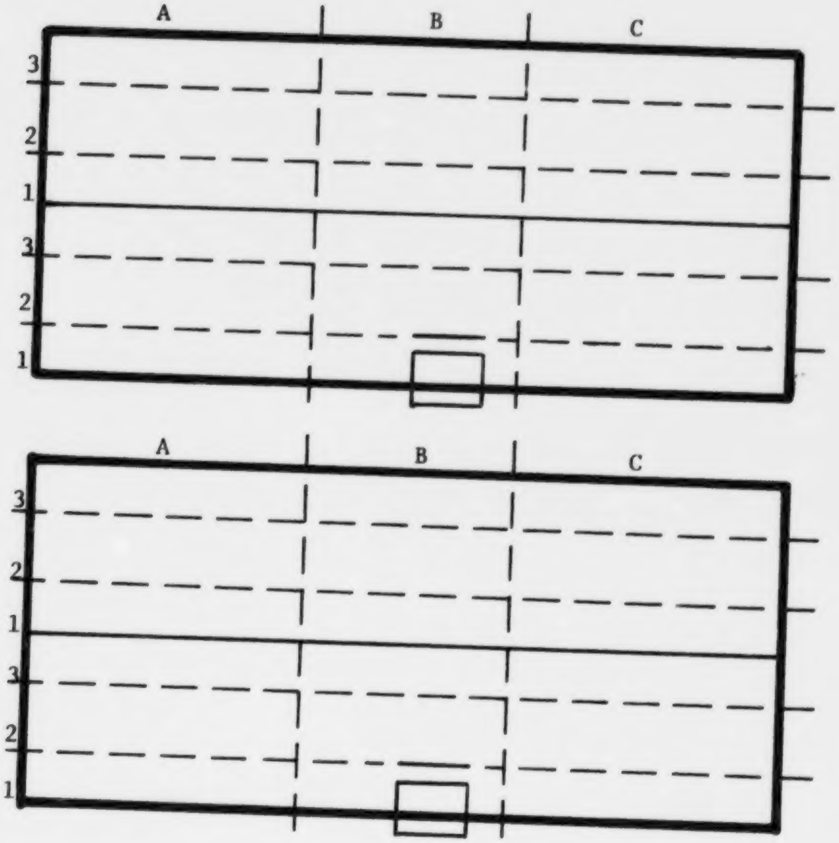
The quantitative benthic survey consisted of taking three samples from each of the four test ponds. Sampling points were located statistically by using an imaginary alphanumeric grid system overlaying each pond. The shallow end of the ponds were designated as "A", the middle as "B", and the deep end as "C". Each alphabetic sector was then further divided into three numeric sections, the southern most side was assigned the numeral "1", the middle "2", and the northernmost was assigned "3", (see Figure 7). Sampling points were then chosen by random selection during the first year and by directed selection the subsequent two years.

Ponar grab samples were chosen as the best method of securing benthic samples. All four test ponds had comparatively hard substrates. Therefore, the use of a Ponar grab sampler was appropriate [51, 52, 53, 54]. The Ponar grab has an effective sampling area of 23 x 23 centimeters (0.0529 m^2) and weighs approximately 23 kg as used in this study. Upon retrieval the samples were placed in containers and then immediately washed through a No. 30 U. S. Standard Sieve. Fines and silts were washed out leaving all specimens and particles larger than 0.0515 centimeters. The entire residue remaining on the screen was then preserved in 70 percent ethyl alcohol. Macroinvertebrate animals were hand picked from all samples and taken to the laboratory for identification, counting, and cataloging.

Fish - The fish community (various species of the genus Lepomus sp.) was sampled by angling during the first year of the study (1971). Fish taken from the test ponds were iced and subsequently taken to the laboratory for tissue

FIGURE 7

Alphanumeric Grid Used to Locate Benthos Sampling Points


A
B
C
3
2
1
3
2
1
A
B
C
3
2
1
3
2
1

taste analysis. Several changes in fish sampling procedures were made during 1972. These changes consisted of using fish from a hatchery and confinement of these fish in live boxes (2. 1 x 2.1 x 1.1 meters) located at a set distance from the engines. These fish were collected from the live boxes with a small seine net on the sampling schedule shown in Table 5.

Analytical Procedures

Periphyton - Periphyton samples were collected for three types of analyses: diatom species proportional counts, dry and ash-free weight, and chlorophyll. Replicate samples were treated independently in a manner similar to the techniques described by Slack, et al.[55] and Weber[47]. All slides were scraped with a razor blade and the periphyton material stored in the respective collection bottles until processed.

Samples used for species identifications were permitted to settle for a period of 24 hours. The preservative was drawn off the sample under low vacuum and the organic material was oxidized with 30 percent hydrogen peroxide and a very small amount of potassium dichromate[56]. Cleaned material was washed with distilled water and permanent slide mounts were made using Hyrax mounting media. Slides were scanned and diatoms were identified and counted under high magnification. Random strips were examined until a minimum of 250 entire frustules were tallied. Species dominance was recorded as a percent relative to the total number of cells counted[47]. Counts of 1972 samples were converted to give estimated numbers/cm^2. This was accomplished by adapting the "drop method" of slide preparation used by Lackey[57]. With this technique the area examined on the slide is quantified as is the area sampled.

TABLE 5

FISH SAMPLING SCHEDULE

Date	Fuel Stress Load Gal. Fuel Burned/Million Gal.	Fish Taken Per Live Box*	
		Stressed	Control
5 May 72	1.5	1	1
18 May 72	4.0	1	1
22 May 72	7.5	2	1
27 May 72	12.5	2	1
10 Jun 72	26.5	2	1
8 Jul 72	54.5	2	1
5 Aug 72	82.5	2	1
2 Sep 72	110.5	2	1
29 Sep 72	1.5**	2	1
7 Oct 72	4.2	2	1

* There were two (2) live boxes per stressed section and one live box per control section.

** Fish taken to verify previous tainting results.

Samples for gravimetric biomass were filtered onto prewashed, tared glass fiber filters (47 mm diameter, 0.45μ porosity). The filtrate was rinsed with distilled water, dried at 100°C for 24 hours, cooled in a dessicator, and weighed. The material was then ashed in a muffle furnace at 500°C for one hour, cooled, rewet with disstilled water, and dried for 24 hours at 100°C. After drying, the samples were weighed and dry weight and ash-free dry weight was calculated[47, 55]. Data was reported as biomass (g/m^2) and production (g/m^2/day). Production is calculated as the organic biomass produced over a given period of time, i.e., the collected organics divided by the number of days the growth was permitted to accrue.

Chlorophyll determinations were made in accordance to the Trichromatic Method, as outlined in Standard Methods[21]. Slides with periphyton were permitted to steep in 80 ml of 90 percent acetone solution for several days in the dark in a freezer. After extraction, an aliquot of the supernate was drawn from the sample and abosrbance was read on a Bausch and Lomb Spectronic 20 at wavelengths of 665 nm, 645 nm, and 630 nm. Chlorophyll a was calculated from the following formulas:

1) $C\underline{a} = 11.6\ D_{665} - 1.31\ D_{645} - 0.14\ D_{630}$

where D = optical density recorded at the specified wavelengths (subscripts)

2) $\text{mg Chl}\underline{a}/\text{m}^2 = C\underline{a} \times \text{volume of extract (liters)} / \text{area of substrate (m}^2)$

Data was recorded as chlorophyll a (mg/m^2) and production (mg Chl.a/m^2/day). Production is the amount of chlorophyll collected which represents a given period of time. The calculated chlorophyll (mg/m^2) is divided by the number of days the slides were permitted to incubate in the test ponds. The derived value is chlorophyll produced per day (mg/m^2/day).

The data gathered from the species proportional counts were used to calculate species richness (diversity) and population similarity as previously discussed.

The autotrophic index, $\frac{\text{ash-free weight } (g/m^2)}{\text{chlorophyll } \underline{a} \ (g/m^2)}$ was used to compare community types[47]. In this formula high levels of organic material or hetrotrophic organisms increase the value which reflects organic pollution.

Phytoplankton -

Population measurements - Species abundance and occurrence were determined from 150 ml subsamples taken in replicate from the composite collections and preserved with 5 to 10 ml's of Lugol's iodine solution[21]. Replicate samples were examined during 1971-1972 while only single samples were examined during 1973. Aliquots from the subsamples were removed after thorough mixing and placed in plankton counting chambers for examination with invertered lens microscopes. A Wild model M-40 microscope using a 10 ml counting chamber with a cover glass surface area of 490.6 mm^2 and a Unitron model BN-13 microscope using a 2 ml counting chamber with a cover glass surface of 126.7 mm^2 were used for all phytoplankton species analysis. Samples were examined and species were enumerated by counting individuals from random transects and grids at a 400X magnification. A factor relative to the surface area examined in each sample was determined and data reported as number of individuals per milliliter natural water. The techniques of the inverted lens microscope procedure are reviewed by Lund[58]. Taxonomic keys used for phytoplankton identifications included Prescott[59], Smith[60], Patrick and Reimer[56], Hustedt[61], and Pascher[62].

Phytoplankton cell count data from 1971 was converted to biomass ($\mu g/l$) in accordance to cell volumes and number of individuals[21]. For each species the volume per cell was estimated by employing micrometer measurements of several individuals (at least ten) and computation formulas for the volumes of standard geometric shapes which the cells closely approximated. Biomass was computed from the volume estimated by assuming a density of 1 g/cm^3 for species other than diatoms and 1.1 g/cm^3 for diatoms. Biomass per cell multiplied by cells per liter yielded biomass estimates per liter for each quantitatively important species in each pond on each 1971 sample date. Although biomass estimates obtained from this technique are approximate values, these values are more valid than straight numerical determinations of dominant organisms (numbers/ml).

Cell count data from 1972-1973 was expressed as number of individuals/ml. Comparisons with time and against treatment conditions were accomodated through total numbers, species diversity, population similarity, and dominant groups (percent abundance).

During 1972 a collection of daily samples was made to study short term population dynamics of the phytoplankton population. Samples were collected over a five-day period, August 12 - August 16, 1972. Two independent whole water samples were collected from each of the test and control ponds on a daily basis. These samples were treated and observed microscopically in the manner previously described.

Primary productivity - From routine composite collections, subsamples were taken for ^{14}carbon productivity measurements. Following thorough mixing of the composite collections, subsamples were transferred into two "light" bottles and one "dark" bottle each of 125 ml capacity. This procedure was most often replicated, but during 1973 some replications was excluded in favor of other experiments. Each test bottle was injected with one ml of ^{14}carbon tracer solution ($NaHC^{14}O_3$) by an automatic syringe with a teflon needle. After injection with the ^{14}carbon tracer solution all test bottles were immediately incubated for four hours at a depth of three feet in a test pond. After incubation, the test bottles were removed from the pond and the respective subsamples were filtered through prerinsed membrane filters (47 mm diameter, 0.45μ porosity). Each bottle was rinsed with distilled water and the wash was filtered also. The filters were rinsed with distilled water to remove all inorganic ^{14}carbon from the filtrate. Filters were air-dried in a dust free chamber for 24 hours then glued into low radioactivity stainless steel planchets. The activity of the individual filtrates was then counted for several ten minute periods in a proportional gas flow, ultra thin window scintillation counter (Beckman-Sharp Laboratories Low Beta II). The recorded beta counts were converted to mg C fixed/m^3/day with the following formula:

$$P = \frac{r}{R}\,(C)\;(F)$$

where: P = mg C produced (fixed)/m^3

$r = \dfrac{\bar{X}\text{ light bottle} - \bar{X}\text{ dark bottle}}{\text{elapsed time of counting}}$

R = carbon added to incubation bottle

C = total inorganic carbon

C = total alkalinity x 0.25

= total alkalinity x 0.25 x 10^3 (if pH >7.0)

F = isotope correction factor

= 1.064

In an effort to more closely relate ^{14}carbon productivity to the phytoplankton associations between test ponds, chlorophyll *a* analyses were added during the 1973 collection period. The analysis of chlorophyll *a* was similar to the techniques described by Richards with Thompson (63) and Standard Methods (21). From the previously discussed composite samples, 150 ml subsamples were removed for filtration and pigment extraction. Subsamples, were filtered onto 47 mm diameter, 0.45μ porosity Gelman membrane filters. Filters were then rolled, filtrate to the inside, and placed in 20 ml capacity screw cap vials. Vials were stored in the dark in a freezer for several days prior to extraction. Ten or fifteen milliliters of extraction solvent (90 percent acetone: 10 percent ethanol) were added to each vial and the samples were returned to the freezer to complete the pigment extraction. After several days of extraction with occassional manual shaking, samples were centrifuged and absorance read at wavelengths of 665 nm, 645 nm, and 630 nm on a Bausch and Lomb Spectronic 20. Chlorophyll *a* was calculated from the following formulas: (21)

$$1)\ \ C\underline{a} = 11.6\ D_{665} - 1.31\ D_{645} - 0.14\ D_{630}$$

$$2)\ \ \text{mg Chl. }\underline{a}/\text{m}^3 = \frac{C\underline{a} \times \text{volume extract (l)}}{\text{volume collected } (\text{m}^3)}$$

Derived chlorophyll *a* values were compared between collection dates and between test ponds to determine significant variations.

An experiment to determine the efficiency of the above chlorophyll extraction procedure was conducted where 90% acetone/10% ethanol solvents were compared. In this experiment absorbance was read on both a Bausch and Lomb Spectronic 20 and a Varian Techtron to compare the effects of instrumentation on the variations of calculated chlorophyll *a*. This experiment is discussed in the "Results" section.

Chlorophyll *a* was compared to ^{14}carbon productivity measurements calculated from same-day collections. This was accomplished with a productivity index, $\frac{\text{mg C fixed/m}^3\text{/hr. (48)}}{\text{mg Chl. }\underline{a}/\text{m}^3}$, which had the net result of mg C fixed/hr./mg Chl. *a*. Using this index, lower numerical values indicate decreased photosynthetic efficiency.

Photosynthetic Inhibition - Subsamples were taken from the composite surface and submerged samples (before and during engine runs) and from the engine cooling water, and measured for chlorophyll a, ^{14}carbon production, and general cell counts. Subsample volumes of 150 ml were removed and filtered onto membrane filters for pigment extraction. These samples were treated in the same manner as the routine samples taken from the four test ponds. Two "light" bottle and one "dark" bottle volumes (125 ml capacity each) were removed from the composite samples and used for ^{14} carbon productivity measurements. The treatment of samples was identical to the methods followed for routine ^{14}carbon productivity measurements. Cell counts were made on the first series of collections in an attempt to determine the effects of turbulence on the resuspension of algal species. Counts were made with an inverted lens microscope, techniques previously described, and taxa were enumerated as belonging to dominant groups, not at the species level.

Zooplankton - The net zooplankton samples were vigorously agitated in order to achieve complete homogeneity and to yield representative subsamples. A 25 ml subsample was drawn from the original sample using an enlarged bore 25 ml class A volumetric pipette and transferred to a 40 ml centrifugation tube. Each sample was then centrifuged at 1500 RPM for 10 minutes and 20 mls drawn off with a 20 ml syringe. The portion drawn off was then scanned with a Bausch & Lomb dissecting microscope at 70X magnification to varify that no organisms were present. The final 5 ml concentrate was then catalogued for identification and enumeration. The taxonomic keys used were Edmondson(64), Pennak(65) Needham and Needham (66), and Gannon(67). Several samples were analyzed prior to fixing for confirmatory evidence on many key characteristics of the Rotifera. For identification and enumeration the Palmer slide was employed in conjunction with a Bausch and Lomb phase contrast photobinocular miscroscope (1972) or a Leitz phase contrast photobinocular miscroscope (1973). The Palmer slide is constructed to hold 0.1 ml of water sample in a mount shallow enough to allow use of the "high dry" (400X) objective (68); this is needed in the identification of many of the animals in the Rotifera. The counting slide was placed on a flat surface and the cover glass was placed diagonally across the cell. A 0.1 ml aliquot was removed with a Pasture pipette and transferred to the Palmer slide. The slide was then placed on a mechanical stage of the calibrated microscope. Counting was accomplished at 100X magnification for all subsamples. All animals enclosed by the Whipple Ocular micrometer were counted. All organisms touching the outer margin of the micrometer were considered as being enclosed by the micrometer. A total of ten random fields were counted for each sample. This number was considered sufficient after several confirmatory countings demonstrated reproducibility of ten independent analytical procedures performed on different slide mounts of the same subsample.

Following the counting procedure a relative net-zooplankton concentration was calculated from the formula:

$$\frac{\text{total count}}{(\text{no. random fields})(0.1\ \text{ml})} \times \text{calibration factor} = \text{zooplankton/ml of sample concentrate}$$

This does not yield a truly indicative number of zooplankton per water volume in the test ponds but does allow accurate and reproducible results for the purpose of comparison between each test system and any other test system. Zooplankton numbers are reported as whole numbers only.

The percent species abundance within a sample was calculated using the formula:

$$\frac{\text{number of individuals of a particular taxa}}{\text{total number of individuals all taxa}} \times 100$$

This formula was modified and applied to determine the percent daily occurrence of particular taxa during the duration of the study and during each sampling season independently. The modification employed was:

$$\frac{\text{number of days a particular taxa occurs}}{\text{total number of daily samples}} \times 100$$

Data generated from the various bio-mathematical indices are reported to two significant figures.

Benthos - All benthic samples (qualitative and quantitative) were treated in an identical manner in the laboratory. After the screened samples were picked the specimens were hand sorted by gross taxonomic characteristics. Groups of taxa were then identified and enumerated under a Bausch and Lomb variable zoom microscope (10X-70X). Identifications were made through the use of the following taxomic keys: Pennak(65), Usinger(69), Needham and Needham(66), Leonard and Leonard(70), Burks(71), Edmonson(72), and Hamilton, et al(73). Indices of species richness, species diversity and similarity coefficients were applied to the data in an effort to determine the likeness or difference between the macroinvertebrate populations of test ponds. These indices have been utilized by Wilhm(74), Bechtel and Copeland(75), and Armstrong, Storrs, and Peterson(76) to reflect environmental changes in natural water systems.

During the 1971 collecting period two formulas of information theory, Shannon-Weaver and Brillouin's, and two simplified species richness formulas were utilized on a comparative basis in an effort to determine the similarity or difference between pond benthos. The comparison of these formulas also indicated which formula (or formulas) was best suited for application to the data collected. During the 1972 and 1973 collecting periods the benthos populations were compared by means of the simplified species richness formulas and similarity coefficients.

Macroinvertebrate biomass determinations were made on all three years (1971-1973) of benthic data. In 1971 this was accomplished gravimetrically, yielding biomass in grams per square meter. During 1972-1973 a volumetric biomass determination was utilized. Mean (average) biomass was then determined in each test pond on each sample date.

Fish - All fish used in the field investigation were purchased from a professional rearing pond in Drifting, Pennsylvania; (Zetts Fish Hatcheries). Various species of the genus *Lepomus* sp. were used in the fish experiments. Upon arrival at the test facility in Saline, Michigan, the fish were placed in the test ponds and their mortality checked prior to stressing the pond waters with outboard engines. At predetermined levels of outboard engine stressing test fish were retrieved from the ponds and taken to the laboratory for taste analysis. Fish samples were cooked at an internal temperature of 83^oC for 30 minutes. Fish tasting was performed by a taste panel. Each panel member was given three coded fish samples, two from the same pond and one from a different pond. The panel members were asked to identify any differences in taste between the three samples, indicate the degree of difference (slight, moderate, and extreme) and to declare if the odd sample was more or less acceptable to them. A "wrong choice" was recorded when a panel member either: 1) Chose a fish from a stress pond as tasting different from the other two fish (taken from a control pond) and indicated that the fish from the stress pond tasted better; or 2) When a panel member chose one of the fish from the control ponds as tasting different than the other two fish (one fish from the stress pond and the other fish being from the control pond).

Statistical Tests and Population Indices - Statistical tests express the degree of belief or disbelief as a probability rather than a general statement. Probability statistics provide a summarization of observed variables from which to objectively draw inferences concerning statistical populations relative to sample characteristics. Reliable numerical information is obtained for directional thought, but statistical significance is not an end in itself.

Numerical and Statistical Tests - The outboard engine stressing study was designed to utilize paired-comparison statistical testing. Paired-comparisons result from dividing an individual unit so that half receives treatment one, and the other half receives treatment two or control(77). Two ponds were divided with one section being stressed and the other used as control.

The method chosen for analyzing the paired comparisons was the paired t-test. The paired t-test evaluates whether the mean of sample differences between pairs of readings is significantly different from a hypothetical mean which the null hypothesis puts at zero. The standard error over which this is tested is the standard error of the mean difference.

The paired t-test determines the statistics associated with the differences D, defined by:

$$D_i = X_i - Y_1$$

The following statistics are determined:

$$\bar{D} = \frac{1}{n} \sum_{i=1}^{n} D_i \qquad \text{(mean difference)}$$

$$S_{\bar{D}} = \sqrt{\frac{\Sigma D_i{}^2 - \frac{(\Sigma D_i)^2}{n}}{n-1}} \qquad \text{(standard deviation of differences)}$$

$$S_{\bar{D}} = \frac{S_D}{\sqrt{n}} \qquad \text{(standard error of differences)}$$

$$t_s = \frac{\bar{D}}{S_{\bar{D}}} \qquad \text{(test statistic)}$$

The application involved calculation of the statistics: $\bar{X}$ and $\bar{Y}$ (means), $S_{\bar{X}}$ and $S_{\bar{Y}}$ (std. deviations), with the control ponds being designated as X and the stressed ponds as Y. The hypothesis tested was:

Ho: $x_o = y_o$

H_1: $x_i \neq y_i$

d = 95% confidence level
df = n-1 (degrees of freedom)

The F-value defines the acceptance region for the hypothesis being tested. If the calculated value $t^2{}_s$ is greater than the F-value, a significant difference is noted and the null hypothesis is rejected. The statistical examination of lead and cadmium values involving pond 3 suggested an alternate hypothesis of H_1: $x_1 > y_1$ due to the introduction of the metals by engine operation.

A resultant t_s statistic having a negative value signifies an increase in the stressed sections (Y) with a positive t_s value showing an increase in the control section (X). The F_s value (t^2_s table value) is obtained for significance testing within rounding error when the t_s value is squared. If a statistically significant difference between the ponds is calculated, it is designated in the appropriate column. The calculated values are shown in tabular form in the corresponding sections.

Following the identification and enumeration of species in the phytoplankton, periphyton, zooplankton, and benthic marcoinvertebrate communities various numerical indices reflecting community composition were applied to the data. These indices, i.e., species diversity, redundancy, species richness, and similarity coefficients, have been recognized and utilized by many researchers as described by Wilhm(74), Bechtel and Copeland(75), Armstrong, Storrs, and Peterson(76), Simpson(78), and Mosimann(79). These various numerical indices and coefficients have been used to indicate the degree of community change in natural water systems. In this project such descriptions reflect changes in the biological communities with respect to natural factors, as well as, changes due to the stressing of the pond environment with outboard engines. Perhaps the most widely accepted measurements of diversity are based on indices which are derived from information theory(74). Measures of "informational diversity" are expressions of the degree of uncertainty involved in predicting the species identity of a randomly selected individual. The more diverse an assemblage the more uncertain the prediction, and conversely, the less diverse the association the more certain the prediction.

During the fall series of benthic macroinvertebrate collections (August-December, 1971) several indices were applied to the data enabling a comparison to determine the most suitable index or indices as well as to determine the distribution of benthic individuals. To implement random selection of collection locations an imaginary alphanumeric grid system overlying each test pond was established. Each pond was divided into western, middle, and eastern sections, designated sections "A", "B", and "C" respectively. Each alphabetic sector was then divided into three numeric sections, the southern-most section was assigned as number "1", the middle section as number "2", and the northern section as number "3". From each test pond three grids were then chosen for collection at random. After species identification and enumeration the data were compared using the indices that follow:

$$H = \frac{1}{N} \log \frac{N!}{n_1!\, n_2! \ldots n_s!}$$

Informational diversity (Brillouin's formula) where:

N = number of individuals of all species in the collection

n_i ($i = 1, s$) = the number of individuals in each species present

! (factorial) = the product of all positive integers from one to the given number

Assuming reasonally large values of N and n, the logarithims of the gamma (Γ) functions may be approximated by Stirling's formula to yield:

$$H' = \sum_{i}^{s} (n_i/N) \log (n_i/N) \text{ Shannon's formula}$$

Either Brillouin's or Shannon's formula may be appropriate depending on the particular sampling conditions.

Values of these indices are dependent on both the number of species in the collection and the relative distribution of individuals among the species. Collections containing equal numbers of species and individuals may be quite different depending on whether the individuals are predominantly of one species (low diversity) or are represented by individuals spread nearly evenly among the species (high) diversity). Measures of evenness usually involve comparing the observed value of H or H^1 with that maximum value theoretically obtained for a collection with the observed numbers of species and individuals. These equations are as follows:

$$H \max = \frac{1}{N} \log \frac{N!}{\{N/S!\} \; s-r \; \{N/S + 1)!\} r}$$

where: N = total number of individuals

S = number of species
(N/S) = the integer part of N/S
r = N-S (N/S)

$$H^1 \max = (1/S) \log (1/S) - \log_2 S \text{ when N is large.}$$

These expressions give values of the indices if all species in a collection are represented in numbers as equivalent as possible. Evenness can be expressed as

$$J = H/H \max \text{ or } J' = H'/H' \max.$$

Minimum theorretical values of H for a given number of species and individuals is given as

$$H \min = \frac{1}{N} \times \log \times \frac{N!}{(N-S+1)}$$

Another index used was "redundancy".

$$R = \frac{H \max - H}{H \max - H \min}$$

Two expressions of species richness were also used, S-1/lnN (80) and $S/\sqrt{N}$ (81), where:

S = total number of species
N = total number of individuals

Of these, $S/\sqrt{N}$, is not as dependent on sample size as S-1 : lnN, and thereby may be the better formula to use when sample sizes differ(74). Richness is lowest when the community is composed of a single species (richness = 0) (82). Richness increases when limiting or inhibitory factors are removed; the species complex becomes more diverse and the community is commonly referred to as being more stable. Such stability is the combined effect of several species or groups of organisms undergoing minor shifts in population numbers as the result of reproduction and mortality.(83).

When the values derived from these formulae were compared from 1971 marcoinvertebrate data the trends were similar. From this comparison it was decided to use the simpler of the expressions. Thus species richness ($S/\sqrt{N}$) and (S-1/lnN) were applied to benthos, zooplankton, periphyton, and phytoplankton data collected during 1972 and 1973. A second comparison of species richness and Shannon-Weaver species diversity was drawn using phytoplankton data. These comparisons are presented in subsequent sections of this report.

Another set of numerical values applied to the periphyton, phytoplankton, zooplankton, and benthos communities were population similarity coefficients. These coefficients relate populations in terms of the number of species in common as opposed to the total number of species in the respective populations. The two formulas used to calculate similarity (commonly referred to as Jaccord's and Pirlot's, or Sorenson's coefficients (78,79,84) respectively) were:

$c/a+b-c$

$2c/a+b$

where: a = number of species in population "A"
b = number of species in population "B"
c = number of species common to both populations "A" and "B"

The calculated values indicate a percent similarity; the level of significance being chosen arbitrarily or statistically. Brown(84) indicates that researchers of benthic communities often use 0.60 to 0.70 as a level of significant similarity. For this study the 50 percent level was arbitrarily selected as the lower limits of significant similarity. This represents calculated values of 0.33 and 0.50 for the Jaccord's and Pirlot's Coefficients respectively.

It is felt that a more accurate comparison of isolated populations results from the use of richness (diversity) indices in conjunction with population similarity coefficients. Margalef(82) indicates that distinctly different and isolated communities may produce identical diversity values, hence the interpretation of data solely on this basis can lead to completely erroneous conclusions regarding the structure of communities. It is therefore essential to establish population similarities especially in the study of a natural system such as undertaken in this project.

The indices presented above were used consistently in the description and comparison of biological communities in this study. Other indices which were used specialized or adapted to test specific communities, or were only used to analyze data from a given time period.

SECTION V

RESULTS AND DISCUSSION

CHEMISTRY

Water Quality of Experimental Ponds - General Chemistry

During the 1971 stressing season the pond systems were characterized by exceptionally low turbidity and a heavy growth of Chara sp. which tended to stabilize the bottom sediments. In the subsequent stressing seasons (1972 and 1973) the water in all four ponds became more turbid (visual observation). This increase in turbidity resulted in a concomitant decrease in Chara sp. in all four ponds. This Chara sp. reduction during the second and third years resulted in more scour of the bottom sediments in the immediate vicinity of the test engines than was experienced during the first year of the study.

In general, the level of dissolved solids, as a group, tended to increase slightly during the first study year and then leveled off and remained relatively constant during the second and third years (appendices C_1 through C_8). It should be noted that total dissolved solids were not measured directly, but rather, the majority of anions and cations which make up the dissolved solids were measured on an individual basis. A review of Appendices C_1 through C_8 will reveal that this general increase in dissolved solids occurred in all four ponds (both control as well as stress sections). During a brief period in October of 1972 extensive conductivity monitoring took place. An analysis of this data (Appendix C_8) reveals that there was a shift in conductivity levels in individual ponds from the beginning to the end of the month (ranging from approximately 550 to 590 micro mhos at the beginning to 410 to 460 micro mhos at the end of the month). It is of interest to note that while this conductivity shift took place, the"paired" ponds (1 and 2, 3 and 4) responded in an identical manner to each other. The decrease in conductivity during this particular period is most probably due to a shift of anion and cation species solubilities in the water column due to changing water temperatures (Appendix C_9). This type of chemical shifting is normal and is typical of most natural freshwater systems at the onset of winter. Water temperature in the pond systems ranged from a low of 2.0°C in the winter months to a high of 24.5°C in the summer months.

Over the three year period phosphorus levels did not vary significantly for any particular pond (Appendices C_{10} and C_{11}). It should be noted here that the total phosphorus levels for all ponds increased significantly during the 1973 test season (see Appendix C_{10}). A review of Appendices C_{10} and C_{11} indicate that this increase is mainly in the polyphosphorus or particulate fraction (Total Phosphorus - Orthophosphorus). Sufficient data (dissolved phosphorus and particulate phosphorus) is not available to completely explain this phenomena. This anamoly in the phosphorus data is most probably due to the natural process of nutrient recycling within each of the ponds. Another example of the natural processes operating on the ponds is shown in an analysis of the phosphorus (Appendix C_{10}) and nitrogen (Appendices C_{12} and C_{13}) data for 7 Aug 72. A review of these Appendices(C_{10}, C_{12} and C_{13}) indicate a drastic increase in total phosphorus, organic nitrogen and nitrate nitrogen in all four ponds for this sampling day. A review of climatological data indicate that this particular sampling day (7 Aug 72) was preceded by a period of heavy rainfall. Similar shifts in the biological communities were also observed during this period (see Figures 19 and 20 - this report). This nutrient (phosphorus and nitrogen) shift is best explained by the fact of rainfall and subsequent runoff into the experimental ponds.

The nitrogen profiles (organic, nitrate, ammonia and nitrite nitrogen) of all four ponds over the test period are shown in Appendices C_{12} through C_{15}, respectively. A general review of the nitrogen data for each separate pond indicates an overall increase in organic and nitrate nitrogen when comparing 1971 levels with 1973 levels (refer to Appendices C_{12} and C_{13}). This general increase appeared to take place in the middle of the 1972 test year. An analysis of the ammonia and nitrite nitrogen results (Appendices C_{14} and C_{15}) show no such "trend" increase in either of these two constituents over the study period. Again, this chemical shifting appears to be a natural process of the ponds themselves.

In summary some of the nutrient data, as mentioned previously, has shown slight variations over the study period when each pond (test or control) is evaluated separately. All test data indicate that these variations are natural characteristics of the pond system themselves. This is reinforced by the fact that all four ponds responded in the same manner regardless as to whether they were stress or control sections.

Routine monitoring of the pH and dissolved oxygen took place through-out the study and are shown in Appendices C_{16} and C_{17}, respectively. Appendix C_{18} shows the results of suspended solids analysis of the pond systems during 1972 and 1973. Again, variations within a given pond can be observed over

Table 6. CHEMICAL STATISTICS - WATER COLUMN DATA

Paired t-Test - 95 % Confidence Level

Parameter	Year	df	$\bar{Y}$	$s_{\bar{Y}}$	$\bar{X}$	$s_{\bar{X}}$	F value	t_s	t_s^2	sig.
POND 1 VERSUS POND 2										
pH	1971-73	36	8.02	0.28	8.11	0.25	5.48	2.45	6.01	*
Alk.	1972-73	36	175	29	167	37	5.48	-1.93	3.71	
Hard.	1971-73	29	284	31	269	32	5.59	-3.18	10.13	*
Ca	1972-73	14	76	16	74	16	6.30	-1.57	2.45	
Mg	1972-73	14	23	6	23	6	6.30	-1.47	2.16	
Cl^-	1971-73	29	28	9	28	10	5.59	0.93	0.86	
Br	1971-73	27	0.36	0.23	0.43	0.22	5.63	2.33	5.42	
SO_4	1973	2	101	13	88	12	38.5	-10.54	111.07	*
Cond.	1972	31	488	48	475	43	5.55	-7.43	55.26	*
T-P	1971-73	27	0.027	0.027	0.027	0.026	5.63	0.08	0.01	
Ortho-PO_4	1971-73	DATA IDENTICAL								
NH_3-N	1972-73	12	0.034	0.017	0.037	0.031	6.55	0.48	0.23	
Org-N	1971-73	27	0.44	0.45	0.55	0.69	5.63	1.50	2.24	
NO_2-N	1971-73	DATA IDENTICAL								
NO_3-N	1972-73	14	0.26	0.19	0.25	0.16	6.30	-0.95	0.90	
TSS	1973	5	17.0	3.5	18.6	1.1	10.0	0.91	0.83	
TVSS	1973	5	9.1	3.8	8.0	2.1	10.0	-0.55	0.31	
D O	1971-72	44	7.9	3.4	7.4	3.5	5.38	-3.21	10.33	*
Temp	1971-72	70	13.2	7.8	13.1	7.9	5.27	-1.69	2.87	
Pb	1971-73	23	4.0	1.9	3.3	1.7	5.75	-3.28	10.74	*
Cd	1972-73	20	0.4	0.4	0.2	0.2	5.87	-1.83	3.36	
Pb (1 v 3)	1971-73	24	4.3	2.2	5.8	3.7	4.26	2.38	5.68	*
(2 v 3)	1971-73	23	3.3	1.7	5.7	3.7	4.26	3.97	15.76	*
POND 3 VERSUS POND 4										
pH	1971-73	36	8.04	0.03	8.22	0.25	5.48	5.55	30.77	*
Alk.	1971-73	36	174	25	166	27	5.48	-3.04	10.95	*
Hard.	1971-73	29	292	32	283	34	5.59	-3.15	9.92	*
Ca	1972-73	14	78	16	72	15	6.30	-2.98	8.86	*
Mg	1972-73	14	24	6	24	6	6.30	0.32	0.10	
Cl^-	1971-73	29	27	8	27	8	5.59	-2.43	5.90	*
Br	1971-73	27	0.41	0.25	0.43	0.24	5.63	1.26	1.59	
SO_4	1973	2	97	10	100	13	38.5	1.15	1.33	
Cond.	1972	31	470	55	435	39	5.55	-10.54	111.07	*
T-P	1971-73	27	0.033	0.047	0.034	0.041	5.63	0.30	0.09	
Ortho-PO_4	1971-73	DATA IDENTICAL								
NH_3-N	1972-73	12	0.022	0.012	0.030	0.023	6.55	1.35	1.82	
Org-N	1971-73	27	0.48	0.57	0.42	0.47	5.63	-0.84	0.71	
NO_2-N	1971-73	DATA IDENTICAL								
NO_3-N	1972-73	14	0.30	0.24	0.28	0.25	6.30	-0.53	0.28	
TSS	1973	5	19.1	4.5	25.8	8.6	10.0	2.49	6.19	
TVSS	1973	5	8.5	2.4	14.8	9.4	10.0	1.45	2.10	
D O	1971-72	44	8.1	3.4	8.6	3.1	5.38	3.62	13.08	*
Temp	1971-72	70	13.1	7.7	12.7	7.8	5.27	-4.66	21.68	*
Pb	1971-73	24	5.8	3.7	4.6	3.1	4.26	-2.97	8.82	*
Cd	1972-73	20	0.4	0.5	0.6	0.4	4.35	-0.64	0.40	

the course of the study but all pond "pairs" (Ponds 1 and 2; pond 3 and 4) responded in a similar fashion.

The previous discussion on the general chemistry of the pond system keynotes the fact that when an individual pond is analyzed in a chronological manner certain chemical components of the pond water did vary. However, in most cases, these variations were a natural phenomena of the ponds and emphasizes the fact that the ponds were natural water systems exposed to natural conditions and that they were dynamic systems.

This is why the particular experimental configuration for this study was chosen. As has been mentioned previously, the ponds were divided in such a fashion that each stress test section had its own integral control section (Figure 1). This allowed the collected field data to be analyzed and evaluated on a "paired" basis, i.e. stress section versus its associated control section (i.e.,pond 1 versus pond 2). This approach eliminated the problem of having to evaluate two separate ponds in close proximity to each other where one pond was a control while the other pond served as a stress test pond. Experience has shown that adjacent water systems are not always completely identical (85). This "paired" pond design also eliminated the reliance on only one control pond and allowed for the collected field data to be statistically analyzed by such methods as: "paired-t", covariance and correlation coefficient procedures etc.

Even with this "paired" approach to data collection and analysis, complications in data interpretation are sometimes unavoidable. Table 6 shows a "paired-t" testing of all the chemical data collected during the test period on the water column. This testing was performed at the

95 percent confidence level. The statistical testing compared each stress section with its associated control. Thus, for the non-leaded fuel stressing analysis, Pond 1 (non-leaded test section) was compared with Pond 2 (control section). Likewise, Pond 3 (leaded test section) was compared with Pond 4 (control section) for the leaded fuel stressing analysis. It should be noted, before any further discussion, that Table 6 reports significance (sig. in Table) on a purely statistical basis. In other words, no account of sampling or analytical variations have been considered.

In Table 6 it can be observed that five chemical components of the water column show significant differences between ponds 1 and 2, non-leaded fuel stress section and control section respectively. These five components are pH, hardness, sulfates, conductivity and lead. When a comparison of Pond 3 versus Pond 4 (leaded fuel stress section versus its associated control section) is made; nine chemical components in the water column show significance, namely pH, alkalinity, hardness, calcium, chlorides, conductivity, dissolved oxygen, temperature and lead.

The significant differences, regardless of whether the "paired" ponds were Ponds 1 and 2 or Ponds 3 and 4, reported for hardness, calcium, chlorides, sulfates, and conductivity is most probably due to the scouring of the bottom sediments by the test propellor wash. In all cases the five above-mentioned chemical components were higher in the test section water column than in the associated control section water column. This perturbation of the bottom sediments is more a result of physical sizing (average water depth of 6 feet) of the test facility and would be atypical of normal outboard motor operations in deeper waters. Thus, it is concluded that the significant differences reported above cannot be attributable to two-cycle outboard exhaust emissions per se but rather to the physical operation of these engines in shallow water (<6 feet).

Table 6 shows that there was a statistically significant difference in dissolved oxygen and temperature when Ponds 3 (leaded fuel stress section) and 4 (control section) were compared. Statistically significance in dissolved oxygen was also observed when the non-leaded fuel stress section (Pond 1) was compared with its associated control (Pond 2). Since over 80 percent of these dissolved oxygen measurements were recorded in 1972 this significance applies to the 1972 test year only. Pond 4 (control) had a higher dissolved oxygen level than its associated test section (Pond 3), even though Pond 3 experienced turbulence due to engine operation, which would tend to increase the re-oxygenation rate of the system. Algal activity was slightly higher in Pond 4 than in Pond 3 beginning on or about 21 Sep 72 for a one month duration (see Figure 20, this report). This higher trend continued into the 1973 test year which is reflected by the higher chlorophyll a levels noted in Pond 4 with respect to Pond 3 (Figure 27). A review of phytoplankton data for Ponds 1 and 2 during 1972 (Figure 19) indicate a larger phytoplankton population in Pond 1 than in Pond 2. The mean dissolved oxygen concentration was higher in Pond 4 than in any of the other three ponds. This leads one to conclude that the significant difference observed between Ponds 3 and 4 and 1 and 2 is most probably due to biological activity within the control rather than an effect of outboard engine stressing.

The mean difference in temperature (ΔT) between Ponds 3 and 4 was 0.5°C over the three year period. This difference although statistically significant is within the accuracy of the field temperature measuring procedures. Therefore, no effect on water temperature can be attributed to the stressing by outboard engines except in the immediate vicinity of the engine (see Section IV. this report).

Hydrogen ion concentration (pH) showed significance when both stress sections were compared with their respective controls (see Table 6). Slightly higher hydrogen ion concentrations were observed in the stress sections (Ponds 1 and 3) than in their respective controls (Pond 2 and 4) - see Appendix C_{16}. This minor pH shift might possibly be due to carbon dioxide (CO_2) that is added to the water column by the gaseous emissions from the two-cycle outboard engine(86). Regardless, this possible CO_2 input had no substantial effect on the alkalinity of the water in the stress ponds. A "paired-t" analysis of Pond 1 and Pond 2 showed no significance in alkalinity between these two ponds. A statistically significant difference in alkalinity between Pond 3 (stress section) and Pond 4 (control section) was observed. A review of Appendix C_5 showed a decrease in alkalinity in Pond 4 (control section) during the late summer months of 1972 and 1973. During other periods the alkalinity in Pond 4 (control) pretty well paralleled the alkalinity in Pond 3 (leaded fuel stress section). The downward shifts in alkalinity in Pond 4 during these two late summer periods accounted for a significance being observed between Ponds 3 and 4. During these two late summer and fall periods in 1972 and 1973, algal activity was higher in Pond 4 than in Pond 3 (Figure 20 and 27 , this report). This increased biological activity could lead to preferential consumption of carbonates by the biological communities with a resulting decrease in carbonate alkalinity (87). This phenomenon could possibly explain the lower alkalinities observed during the late summer months of 1972 and 1973 in Pond 4.

Heavy Metals - Lead and Cadmium in Water Column

The study of the trace metals lead (Pb) and cadmium (Cd) in the water column of the various ponds yielded results in general agreement with anticipated concentrations based on theoretical considerations of water chemistry (see discussion in section IV - this report). The rational for monitoring cadmium has been discussed previously.

A review of the aqueous lead data, as shown in Table 7, reveals a relatively steady increase in the level of lead in the water column of Pond 3 (leaded fuel stress test section) during the 1972 stressing season. From Table 7 it is also apparent that the lead level in Pond 4 (associated control for Pond 3) increases throughout the 1972 stress season. This at first suggested a possible water exchange between Ponds 3 and 4. This was not the case as underwater observations by scuba divers indicated that the aluminum dividing wall was intact and no leaks were found. A more likely reason for the lead level increase noted in Pond 4 is the fact of the close proximity of Pond 4 with Pond 3. Periodically, throughout the study it was noticed that the airborn exhausts from the engines operating in Pond 3 were carried over the dividing wall and across the surface of Pond 4. It has been reported in the literature (88) that much of the lead present in the combustion

TABLE 7

LEAD in WATER COLUMN
(µg/l)

DATE	TYPE OF SAMPLE	Pond 1	Pond 2	Pond 3	Pond 4
5 Oct 71	Composite	9.8	8.4	18.2	12.6
12 Oct 71	Composite	9.8	–	8.4	11.9
1 Dec 71	Composite	6.0	4.0	3.0	3.0
8 Jun 72	Composite	2.0	1.0	1.0	1.0
17 Jul 72	Composite	2.8	1.8	1.7	1.2
24 Jul 72	Composite	2.7	1.8	2.6	1.8
31 Jul 72	Composite	1.3	2.2	3.0	2.8
7 Aug 72	Composite	2.6	2.0	4.4	2.8
14 Aug 72	Composite	3.7	2.0	4.1	2.0
21 Aug 72	Composite	5.7	1.7	2.9	2.3
28 Aug 72	Composite	2.9	2.9	4.8	3.1
11 Sep 72	Composite	3.2	2.1	3.9	<0.4
18 Sep 72	Composite	2.9	1.8	6.4	2.9
25 Sep 72	Composite	3.0	2.6	6.2	4.7
2 Oct 72	Composite	3.3	3.3	7.6	5.7
9 Oct 72	Composite	1.8	2.1	5.7	3.5
16 Oct 72	Composite	2.7	3.5	10.7	7.4
23 Oct 72	Composite	4.9	2.1	11.0	9.1
30 Oct 72	Composite	7.1	5.4	9.0	5.4
11 May 73	Composite	5.1	5.4	5.8	4.3
29 May 73	Composite	5.5	4.6	6.6	5.7
18 Jun 73	Composite	5.2	5.5	4.0	5.1
2 Jul 73	Composite	5.8	4.8	4.3	5.8
23 Jul 73	Composite	3.4	4.2	4.5	3.6
21 Aug 73	Composite	3.5	3.0	3.9	6.1

Composite refers to a) surface and middle samples taken at Station A
b) surface and middle samples taken at Station B
c) surface, middle, and depth samples taken at Station C
(reference Figure 5 this report)

process exists with the exhaust gases in the form of aerosols and ultimately is removed from the air through precipitation. Thus, it is possible that the increase in lead concentrations observed in Pond 4 during 1972 could be the result of aerosol transport from the exhaust exiting from the engines being operated in Pond 3.

The relatively steady increase in lead concentration in the water column of Pond 3 observed during the 1972 season was not noticed during 1973 (Table 7). In addition, the maximum lead level observed during 1973 was 6.6 μg/l as compared to 11.0 μg/l during 1972 and 18.2 μg/l during the 1971 stressing season (Table 7). No satisfactory explanation for the phenomena has been made. The concentration of sulfate ion (Appendix C_6) measured during 1973 never reached the level where it would limit the lead solubility in the water ($K_{sp} = 10^{-7.8}$) and the concentration of carbonate ion (Appendix C_2) though potentially solubility limiting ($K_{sp} = 10^{-13.1}$), varied insignificantly during 1972 and 1973. The possibility of a change in sulfide ion concentration could possibly account for a change in the solubility of lead ($K_{sp} = 10^{-27.5}$) though such an explanation is only speculative because sulfide was not monitored during the study.

Cadmium levels (Table 8) show little or no variation in concentration in the water column during the course of the study. No particular "trend" was noticed in the cadmium levels in the aqueous phase.

In the statistical testing of lead and cadmium concentrations in the water column (Table 6), significant

TABLE 8

Cadmium Levels in Water Column

DATE	TYPE OF SAMPLE	CADMIUM (µg/1) Pond 1	Pond 2	Pond 3	Pond 4
8 Jun 72	Composite	<1.0	<1.0	<1.0	<1.0
17 Jul 72	Composite	0.1	0.1	0.1	0.2
24 Jul 72	Composite	0.2	0.1	0.3	0.1
31 Jul 72	Composite	0.1	<0.1	0.1	<0.1
7 Aug 72	Composite	0.1	<0.1	0.1	<0.1
14 Aug 72	Composite	0.1	0.2	<0.1	0.2
21 Aug 72	Composite	1.8	0.5	1.1	0.2
28 Aug 72	Composite	0.2	0.1	0.2	0.2
11 Sep 72	Composite	0.7	0.7	0.7	0.5
18 Sep 72	Composite	0.1	<0.1	0.1	<0.1
25 Sep 72	Composite	0.5	0.2	0.1	0.2
2 Oct 72	Composite	0.1	0.1	0.1	0.2
9 Oct 72	Composite	0.1	0.1	0.1	0.6
16 Oct 72	Composite	0.2	0.2	0.3	0.1
23 Oct 72	Composite	0.9	0.3	1.4	1.8
30 Oct 72	Composite	1.0	0.9	0.8	0.8
11 May 73	Composite	0.2	0.3	0.2	0.1
29 May 73	Composite	0.2	0.1	2.0	0.3
18 Jun 73	Composite	0.5	0.5	0.5	1.1
2 Jul 73	Composite	0.4	0.5	0.2	0.3
23 Jul 73	Composite	0.2	0.2	0.1	0.2
21 Aug 73	Composite	0.2	0.2	0.3	0.3

Composite refers to a) surface and middle samples taken at Station A
b) surface and middle samples taken at Station B
c) surface, middle and depth samples taken at Station C
(reference Figure 5 this report)

differences were found only in the lead levels. Lead concentrations were significantly higher in both stressed ponds (1 and 3) than in their respective control ponds (2 and 4). Pond 1 exhibited higher levels of lead in the water column than in Pond 2 (its associated control). This significant difference in lead levels between Ponds 1 and 2 (Table 6) can possibly be explained by the scouring of sediment bottom caused by the propellor wash in the test section (Pond 1). The bottom sediments of the test ponds (1 and 3) contain between 10 and 40 mg/Kg of lead (Appendix B_5). The resuspension and subsequent resolution of this sediment material could possibly raise the total lead content observed in the water column of the test sections. As expected, when the lead levels found in Pond 3 (leaded fuel test section) was evaluated against the lead levels found in Ponds 1 and 2 a statistical significance was observed (Table 6).

It became obvious from these statistical comparisons that Pond 3 could not be compared with its associated control (Pond 4) because of the effect of bottom scouring in the engine stress pond and the possible aerosol carry over (containing lead) from Pond 3 to Pond 4. For these reasons it was deemed desirable to compare Ponds 1 and 3 directly. By using this comparison the effects of sediment bottom scouring and aerosol transport were compensated for as both Ponds 1 and 3 are stress ponds and only non-leaded fuel was used in testing Pond 1. Ponds 1 and 3 were evaluated using a "one tailed paired-t" analysis. A significant difference in lead levels was observed between Ponds 1 and 3 (Table 6). There is a 34 percent increase in lead concentration in the water column of Pond 3 as compared to Pond 1. This increase in lead levels is directly attributable to the use of outboard engines operating on leaded fuel.

Heavy Metals - Lead and Cadmium in the Sediments

During the three seasons of stressing, a total of 1.48 kg of lead was introduced to Pond 3 through the combustion of fuel containing 3.1 grams of lead per gallon (see Appendices B_2 and B_3). The effectiveness with which this lead is captured in the water phase by scrubbing is unknown. However, it is reasonably certain that a significant portion would be retained in the water column. As discussed previously, the solubility of lead in the water column is relatively low, thus the majority of the lead captured in the aqueous phase will ultimately be transferred to the sediment phase or the aquatic macrophytes. The pond system utilized in this study was essentially devoid of macrophytic growth, thus the ultimate site for lead accumulation in this system would be the pond sediments.

Analysis of the lead content in the pond sediments (Table 9) and statistical evaluation of this data (Table 11) does not show any significant increase of lead in the Pond 3 sediments. Though the mean lead concentration in Pond 3 is 11 to 65 percent higher than the other three ponds, the data is sufficiently variable that statistical interpretation is difficult. A "paired" statistical comparison between Ponds 1 and 3, as was performed on the aqueous lead data, did not indicate a significant difference between these two ponds. An analysis of the data on cadmium in the bottom sediments (Tables 10 and 11) indicates even less of a variation between ponds than is seen with lead.

As discussed previously, there exists a correlation

TABLE 9

LEAD IN BOTTOM SEDIMENTS

mg/Kg

DATE	SAMPLE STATION*	Pond 1	Pond 2	Pond 3	Pond 4
Oct 72	A	23	8	31	40
Oct 72	B	14	9	15	22
OCt 72	C	17	16	58	21
Nov 72	A	11	12	16	18
Nov 72	B	18	11	31	14
Nov 72	C	44	17	56	16
May 73	A	21	11	43	39
May 73	B	34	18	19	21
May 73	C	19	16	24	57
Jun 73	A	33	12	14	20
Jun 73	B	18	27	20	21
Jun 73	C	47	30	41	28
Jul 73	A	25	10	18	39
Jul 73	B	16	43	24	15
Jul 73	C	15	28	32	26

* Core samples - refer to Figure 5

TABLE 10

CADMIUM IN BOTTOM SEDIMENTS
(mg/kg)

DATE	SAMPLE STATION *	Pond 1	Pond 2	Pond 3	Pond 4
Nov 72	A	0.9	1.1	1.1	1.7
Nov 72	B	1.5	0.9	1.5	1.5
Nov 72	C	2.5	1.3	2.4	1.4
May 73	A	1.2	1.8	3.2	3.3
May 73	B	3.0	1.8	2.4	2.4
May 73	C	2.4	2.1	2.1	3.2
Jun 73	A	1.7	1.0	0.8	1.5
Jun 73	B	1.6	1.9	1.2	1.5
Jun 73	C	2.8	2.5	2.7	2.1
Jul 73	A	1.6	0.8	0.8	2.3
Jul 73	B	2.0	2.5	1.0	1.0
Jul 73	C	0.8	1.7	1.5	1.3

* Core samples - refer to Figure 5

Table 11. CHEMICAL STATISTICS - SEDIMENT DATA
Paired t-Test - 95 % Confidence Level

Parameter	Year	Test Ponds	df	$\overline{Y}$	$S_{\overline{Y}}$	$\overline{X}$	$S_{\overline{X}}$	F value	t_s	t^2_s	sig.
Pb	1972-73	1 vs. 2	14	24	11	18	10	6.30	-1.58	2.50	
	1972-73	3 vs. 4	14	29	14	26	12	4.60	-0.61	0.37	
	1972-73	1 vs. 3	14	24	11	29	14	4.60	1.51	2.27	
	1972-73	2 vs. 4	14	18	10	26	12	6.30	1.89	3.56	
	1972-73	2 vs. 3	14	18	10	29	14	4.60	2.67	7.15	
Cd	1972-73	1 vs. 2	11	1.8	0.7	1.6	0.6	6.72	-1.06	1.12	
	1972-73	3 vs. 4	11	1.7	0.8	1.9	0.7	4.84	1.04	1.08	
	1972-73	1 vs. 3	11	1.8	0.7	1.7	0.8	4.84	-0.46	0.21	
	1972-73	2 vs. 4	11	1.6	0.8	1.9	0.7	6.72	1.24	1.54	
	1972-73	2 vs. 3	11	1.6	0.6	1.7	0.8	4.84	0.48	0.23	
Pb/Cd Ratio (1)											
		Pond 1	13.0								
		Pond 2	11.1								
		Pond 3	17.1								
		Pond 4	13.7								

(1) Ratios are calculated from mean concentrations

between background lead and cadmium levels in the sediment of the pond system. Thus, greater insight into the heavy metal concentration of the sediments is provided by observing the lead to cadmium ratio, as shown in Table 11. As is shown in Table 11, Pond 3 has clearly the highest ratio of lead to cadmium in the sediments. In this comparison (Pb to Cd ratio), the higher lead levels observed in Ponds 1 and 4 are compensated for somewhat by the higher levels in associated cadmium.

Although, there appears to be some increase in lead in the bottom sediments of the pond stressed with leaded fuel, based on statistical testing and comparison of Pb/Cd the data is too variable and limited to allow for a conclusive statement in this regard. Such a statement would require further investigation of transport mechanisms as well as more extensive sampling and analysis of the sediments themselves.

Hydrocarbons in Water Column

Petroleum fuels are complex mixtures of organic molecules consisting primarily of the elements carbon and hydrogen. Such compounds are specified as hydrocarbons. The majority of the components in a fuel such as gasoline fall into one of three classes of hydrocarbons: a) saturates; b) olefins; c) aromatics (38). The class denoted "saturates" includes both alkanes (paraffins) and cycloalkanes (naphthenes). "Olefins" include straight-chain olefins, branched-chain olefins and cyclic olefins. The class "aromatics" include all mono-, di-and polynuclear aromatic species. The chemistry of these three classes of compounds varies significantly. Whereas the saturated hydrocarbons are virtually insoluble in water, many aromatics have appreciable solubility in aqueous solution (89). Similarly, the paraffins and cycloparaffins are relatively stable chemically due to the high degree of saturation, while aromatic compounds are generally more reactive. The chemical and physical properties of olefins are interjacent between those of saturates and aromatics, depending primarily on the degree of saturation of the particular olefin being considered. The difference in the chemistries of these classes of hydrocarbons dictates that they be considered separately when determining the fate of petroleum-derived hydrocarbons in the environment.

As noted earlier (section IV), the aromatic hydrocarbons associated with outboard engine emissions received primary attention during the first part of the study due to their relatively high toxicity(10). The cyclohexane extraction-UV spectrophotometric procedure developed for the University of Michigan laboratory studies(28) was used to monitor changes in the concentration of these aromatics in the stressed and control ponds. This technique is based on the characteristic absorbance of the aromatic E_2 band in the 200-220 nm range(90).

Preliminary data gathered in the 1972 stressing season indicated levels of 10 to 50 μg/l (as toluene) in all of the ponds, with little difference seen between the stressed and control sections.(28,91) However, an abrupt increase of an order of magnitude in the aromatic absorption was observed in water samples taken from stressed ponds as well as controls during late summer 1972 (28). Gas chromatographic analysis of these same samples revealed that none of the low molecular weight aromatic hydrocarbons common to the fuel used in the outboard engines were present. The increased absorption of these samples in the range of 200-220 nm was attributed to a change in the background level of relatively high molecular weight substances containing aromatic rings present naturally in the water column(28). High background levels of such material precluded observing the relatively low levels of low molecular weight aromatic hydrocarbons found to be associated with the combustion of gasoline in outboard engines (92). Further attempts to monitor these low molecular weight aromatics were abandoned when the results of laboratory evaporation studies of outboard motor emission water (OME water) by the University of Michigan revealed that these substances remained in the water column for short periods of time (less than a day) under conditions normally encountered in natural systems(92).

In late summer and early fall of 1972 greater emphasis was placed on the saturated hydrocarbon components of the exhaust. The low solubility of alkanes, cycloalkanes and olefins of high saturation dictate that, if these substances are present in the water column, they will be dispersed as emulsions and/or adsorbed on particulate matter. Consequently, the fate of these saturates in the aquatic environment will be somewhat different than that of the water soluble aromatic hydrocarbons (see section IV). Quantitative infrared spectroscopy was utilized to provide information on the level of saturated hydrocarbons in the water column during October and November of the 1972 stressing season. This technique utilizes a carbon tetrachloride extraction of the sample and measurement of the infrared absorption at 2925 cm^{-1} of the sample extract(29,30). The level of saturated hydrocarbons determined by this technique in the pond samples (test and control sections) ranged from 2 to 10 mg/l, based on a gravimetric calibration curve(29,91). Unfortunately, this IR method was found to be vulnerable to interferences from background non-hydrocarbon material. The absorption of 2925 cm^{-1}, on which the method is based, is due to the $-CH_2-$ asymetrical stretch and is common to a great many organic substances in addition to hydrocarbons. Consequently, the constitutents measured by this IR technique cannot conclusively be labeled hydrocarbons. This fundamental limitation precluded use of the procedure in the study. Consequently, a new analytical procedure to measure saturated hydrocarbons was developed and adopted, for use during the 1973 stressing season.

This new technique to measure saturated hydrocarbons involved a liquid chromatography - gas chromatography (LC-GC) system. This procedure was chosen for its suitability in characterizing hydrocarbons from both the water column and sediments. This technique allows for the separation of saturated hydrocarbons from aromatic hydrocarbons and other hetero-organic substances (e.g. ketones, esters, alcohols, lipids, etc.). These saturates were then fractionated into two boiling point ranges (175-300°C; 300-400°C) to provide information on the origins of these hydrocarbons (e.g. gasoline, lubricating oil, etc.) A typical boiling point

point chromatogram is shown in Figure 8. This fractionation approach also provided qualitative information which aided in predicting the fate of these substances in the ecosystem. It should be noted that this analytical procedure cannot specifically differentiate between a naturally derived hydrocarbon and an exhaust emission derived hydrocarbon. However, an enrichment in the saturated hydrocarbon levels of the stressed ponds when compared to their respective controls can be evaluated quite accurately by this procedure.

Data from the 1973 stressing season on saturated hydrocarbon levels in the water column is presented in Table 12. These data incate saturated hydrocarbon in the 175-300°C boiling point range (corresponding to in molecular weight C_{10}-C_{16} n-paraffins) present in the ponds at the 0.46 to 0.48 mg/l level. Saturated hydrocarbons in the 300-400°C boiling point range (corresponding in molecular weight to C_{17}-C_{24} n-paraffins) are present at the 0.11 to 0.21 mg/l level. No significant differences between the stressed ponds and their respective control ponds can be seen in either of the hydrocarbon ranges. Statistical analysis of this data by a two-tailed paired "t" test confirms that no significant differences exist between stressed and control ponds during this observation period (Table 13). It should be noted that both emulsified and adsorbed hydrocarbon material is included in the analysis of these water column samples by the analytical procedure employed.

Hydrocarbons in Sediments

Results from the analysis of sediment samples for saturated hydrocarbon content are contained in Table 14. Hydrocarbon levels in the 175-300°C boiling point range varied from <0.1 to 25.8 mg/kg dry weight. The over-all mean con-

FIGURE 8

RESOLUTION OF C_{10}-C_{36} EVEN-NUMBERED N-PARAFFIN MIXTURE BY ANALYTICAL DISTILLATION GAS CHROMATOGRAPHY (CHROMATOGRAPHIC CONDITIONS SPECIFIED IN TABLE 4)

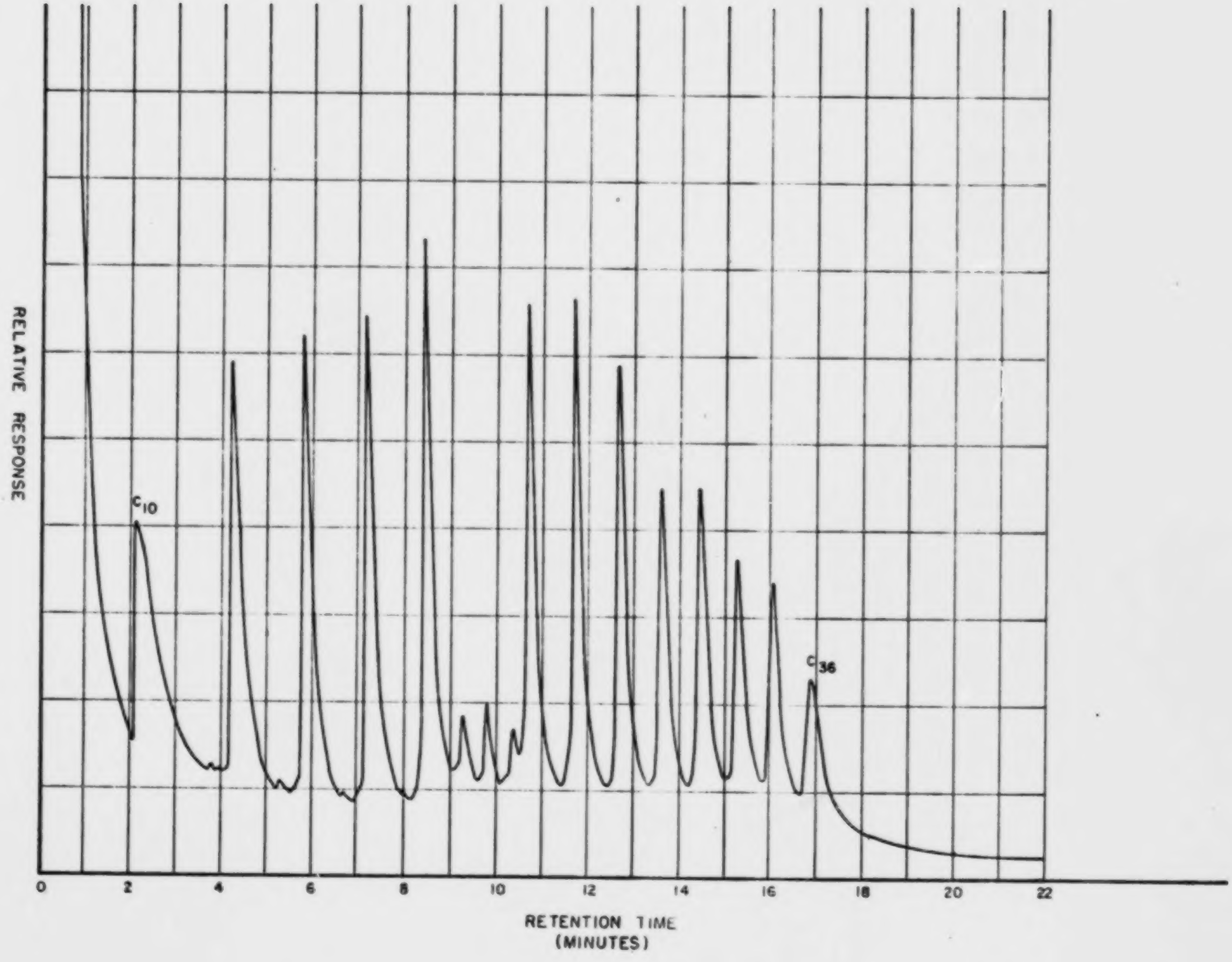


Table 12

HYDROCARBONS* (Boiling Point Range 175-300°C) (mg/l)

Date	Pond 1	Pond 2	Pond 3	Pond 4
15 May 73	0.45	0.40	0.41	0.38
1 Jun 73	0.39	0.40	0.43	0.39
26 Jun 73	0.48	0.42	0.36	0.35
2 Jul 73	0.35	0.35	0.35	0.38
23 Jul 73	0.37	0.37	0.37	0.36

HYDROCARBONS* (Boiling Point Range 300-400°C) (mg/l)

Date	Pond 1	Pond 2	Pond 3	Pond 4
15 May 73	0.13	0.11	0.12	0.11
1 Jun 73	0.11	0.12	0.13	0.12
26 Jun 73	0.15	0.14	0.17	0.19
2 Jul 73	0.18	0.16	0.19	0.20
23 Jul 73	0.21	0.16	0.16	0.17

*Samples are composites of individual samples taken at surface and middle at stations A and B and surface, middle and depth at station C.

TABLE 13

HYDROCARBONS IN WATER COLUMN - STATISTICS

	df	$\overline{Y}$	$S_{\overline{Y}}$	$\overline{X}$	$S_{\overline{X}}$	F value	t_s	t^2_s	sig.
Hydrocarbons 1973									
1 vs. 2 (boiling point range 175-300°C)	4	0.41	0.05	0.39	0.03	12.2	-1.38	1.90	
1 vs. 2 (boiling point range 300-400°C)	4	0.16	0.04	0.14	0.02	12.2	-1.86	3.46	
3 vs. 4 (boiling point range 175-300°C)	4	0.38	0.03	0.37	0.02	12.2	-1.00	1.00	
3 vs. 4 (boiling point range 300-400°C)	4	0.15	0.03	0.16	0.04	12.2	0.67	0.45	

Table 14

Saturated Hydrocarbons in Sediments (mg/kg)
(boiling point range 175-300°C)

Date	Station	Pond 1	Pond 2	Pond 3	Pond 4
15 May 73	A	<0.1	3.2	12.8	11.1
15 May 73	B	6.0	15.3	3.8	<0.1
15 May 73	C	3.4	4.7	<0.1	2.8
18 May 73	A	3.4	3.8	10.5	9.1
18 May 73	B	0.8	2.7	4.0	3.6
18 May 73	C	5.4	5.0	25.8	6.7
23 Jul 73	A	7.5	2.1	4.6	1.8
23 Jul 73	B	5.9	8.7	<0.1	4.3
23 Jul 73	C	4.7	12.9	19.5	0.3

Saturated Hydrocarbons in Sediments (mg/kg)
(boiling point range 300-400°C)

15 May 73	A	4.7	2.9	19.2	7.9
15 May 73	B	11.0	6.4	4.5	3.7
15 May 73	C	5.1	4.0	6.7	3.7
18 Jun 73	A	9.9	1.7	4.6	7.3
18 Jun 73	B	3.1	3.4	6.5	4.2
18 Jun 73	C	16.0	2.3	22.5	6.1
23 Jul 73	A	22.3	1.1	1.6	7.8
23 Jul 73	B	12.3	15.9	0.2	4.6
23 Jul 73	C	8.4	7.6	8.8	5.1

centration of hydrocarbons of this range in the sediments on Pond 1 is about the same as that of Pond 2 (4.1 mg/1 kg versus 6.5 mg/kg respectively). The mean concentration of saturated hydrocarbons (175-300^{o}C range) in the sediments of Ponds 3 and 4 were 9.0 and 8.9 mg/kg, respectively. No definite trend exists between the stressed ponds and their respective controls (ponds 1 vs.2 and 3 vs. 4). Statistical analysis of this data (Table 15) indicates no significant difference between the test and control ponds.

Sediment hydrocarbon concentrations for the 300-400^{o}C boiling point range are also shown in Table 14. The saturated hydrocarbons in this range are of the C_{17} to C_{24} molecular weight range. Alkanes of this size comprise the lighter weight components in lubricating oil (44,93). Evaluation of this data indicates that the stressed section (Pond 1) generally contains more hydrocarbons in this molecular weight range than does its associated control section (Pond 2). The overall mean concentration in the sediments of Pond 1 is more than twice that of Pond 2 (10.3 mg/kg versus 5.0 mg/kg). The other stress section (pond 3) had an average saturated hydrocarbon concentration of 8.3 mg/Kg while its control section (pond 4) yielded an average concentration of 5.6 mg/Kg dry weight. The resultant test statistics showed no significant difference in the high boiling point range for hydrocarbons in the sediments of the ponds. Visual observation of the data seems to indicate a trend with an increase in Pond 1 over Pond 2 and Pond 3 over Pond 4. However this is negated statistically by the small sample size and the high standard error of differences due to the standard deviation of the differences in the sample population.

Table 15. HYDROCARBONS IN SEDIMENT - STATISTICS

	df	$\overline{Y}$	$S_{\overline{Y}}$	$\overline{X}$	$S_{\overline{X}}$	F value	t_s	t_s^2	sig.
Hydrocarbons 1973									
1 vs. 2 (boiling point range 175-300°C)	3	4.13	2.45	6.46	4.80	7.57	1.60	2.56	
1 vs. 2 (boiling point range 300-400°C)	8	10.31	6.07	5.03	4.60	7.57	-2.02	4.08	
3 vs. 4 (boiling point range 175-300°C)	8	9.0	8.9	4.4	3.8	7.57	-1.60	2.56	
3 vs. 4 (boiling point range 300-400°C)	8	8.3	7.6	5.6	1.7	7.57	-1.11	1.23	

BIOLOGY

Periphyton

Species Proportional Counts - Fifty-one species were recognized from the collections of 1972 and 89 species were recognized from the 1973 collections. Eleven species appeared to dominate the 1972 collections; these were (c.f. Appendix C-19):

Achnanthes lanceolata
A. minutissima
Cyclotella stelligera
Cymbella microcephala
Fragilaria brevistriata
Gomphonema species complex
Nitzschia acicularis
N. filiformis
N. palea
Synedra sp. 1 and 2

These taxa had an occurrence equal to or greater than the mean number/cm^2 for each particular sample on each day. The greatest number of individuals appeared in the late August and early September samples with fewer individuals occurring on and after September 23, 1972. It was also observed that population similarity within test ponds, i.e., between Stations A and C, varied with time during 1972. When population similarity between test ponds was compared from 1972 data, there were no large variations in similarity and similarity was most often high (Table 16).

During 1973 there were nine dominant species, some of which were dominant in one collection and not in the other. The dominants included:

Achnanthes Bory (girdle view)
A. linearis (W. Smith) Grun. var. *linearis*
A. minutissima Kuetz. var. *minutissima*

TABLE 16

PERIPHYTON SIMILARITY WITHIN PONDS
SORENSONS SIMILARITY COEFFICIENT $\frac{2c}{a+b}$

Date	Pond 1 Stations A-C	Pond 2 Stations A-C	Pond 3 Stations A-C	Pond 4 Stations A-C
9 Aug 72	0.83	0.88	0.86	0.89
8 Sep 72	0.94	0.79	0.84	0.70
23 Sep 72	0.86	0.83	0.65	0.82
13 Oct 72	0.82	0.89	0.81	0.81
3 Nov 72	0.85	0.78	0.78	0.64
30 Nov 72	0.70	0.85	0.65	0.79
2 Jul 73	0.59	0.45	0.63	0.74
17 Aug 73	0.57	-	0.61	0.60

PERIPHYTON POPULATION SIMILARITY - STRESS VS. CONTROL*

Date	Pond 1 vs. 2	Pond 3 vs. 4
9 Aug 72	0.79	0.84
8 Sep 72	0.83	0.76
23 Sep 72	0.75	0.84
13 Oct 72	0.84	0.76
3 Nov 72	0.87	0.70
30 Nov 72	0.75	0.68
2 Jul 73	0.55	0.66
17 Aug 73	-	0.48

---

* Values are derived from the composite species list of two stations within each pond, e.g. Pond 1 (Stations A + C) compared with Pond 2 (Stations A + C), etc.

Cyclotella glomerata Bach.
Nitzschia acicularis W. Smith
N. frustulum Kuetz.
N. kuetzingiana Hilse
N. palea (Kuetz.) W. Smith
Synedra crotonensis var. *prolongata* Grun in V.H.

Community similarity of species associations comparing stations within test ponds as well as between test ponds is presented in Table 16. On the two 1973 collection dates there was similarity within ponds except in Pond 2, July 2, 1973, where similarity was 0.45; a value of 0.50 being arbitrarily established as the lower limit of similarity. Comparison of similarity between pond-pairs, Pond 1 (non-leaded stress) to Pond 2 (control) and Pond 3 (leaded stress) to Pond 4 (control), showed a low similarity between Ponds 3 and 4 (0.48).

Species richness ($S/\sqrt{N}$ and $S-1/\ln N$) Table 17, was higher during the 1973 collecting period than during 1972. A paired t-test, 95 percent confidence level, was used to compare richness from the shallow ends of Ponds 1 and 2, Ponds 3 and 4, and from the deep water ends on Ponds 1 and 2, and Ponds 3 and 4. The results indicated no significant differences in species richness occurred between pond-pairs. Essentially the pond-pairs were comprised of similar diatom associations in the periphyton community.

Gravimetric Biomass, Chlorophyll, Autotrophic Index - Ash-free dry weight (organic weight) biomass (g/m^2) and production ($g/m^2/day$) are presented in Table 18. These data are compared between test ponds and between collection dates in terms of organic production. Comparisons in terms of biomass may be misleading as incubation periods varied

TABLE 17

PERIPHYTON RICHNESS (S-1/lnN)
COMPARING STATIONS WITHIN CONTROL AND STRESS TEST PONDS

Date	Pond 1A	Pond 1C	Pond 2A	Pond 2C	Pond 3A	Pond 3C	Pond 4A	Pond 4C
9 Aug 72	2.41	1.62	2.09	1.94	1.79	1.95	1.82	1.86
8 Sep 72	1.83	2.00	2.02	2.18	1.78	1.49	2.29	2.65
23 Sep 72	2.10	2.86	2.25	2.48	1.85	2.10	2.37	2.09
13 Oct 72	2.01	2.38	1.79	2.24	2.06	1.34	2.21	2.09
3 Nov 72	3.25	3.09	2.84	2.29	2.27	2.72	3.27	1.57
30 Nov 72	2.11	2.27	3.65	2.66	1.92	1.98	1.70	1.71
2 Jul 73	6.70	4.32	6.34	3.39	6.00	4.98	3.27	4.48
17 Aug 73	4.93	5.24	-	-	4.18	3.99	2.78	3.74

PERIPHYTON RICHNESS (S/$\sqrt{N}$)

Date	Pond 1A	Pond 1C	Pond 2A	Pond 2C	Pond 3A	Pond 3C	Pond 4A	Pond 4C
9 Aug 72	0.10	0.06	0.14	0.12	0.08	0.08	0.17	0.18
8 Sep 72	0.06	0.08	0.10	0.10	0.08	0.08	0.13	0.15
23 Sep 72	0.18	0.25	0.17	0.20	0.15	0.18	0.13	0.12
13 Oct 72	0.12	0.12	0.08	0.10	0.13	0.08	0.16	0.10
3 Nov 72	0.62	0.31	0.21	0.13	0.26	0.30	0.31	0.14
30 Nov 72	0.27	0.26	0.27	0.15	0.11	0.20	0.10	0.10
2 Jul 73	1.22	1.23	1.75	1.10	1.74	1.63	1.09	1.49
17 Aug 73	1.70	1.78	-	-	1.42	1.34	0.95	1.22

Table 18. PERIPHYTON PRODUCTION

Date & Station	Organic Wt. g/m^2	Org. Production g/m^2/day	Chl. a mg/m^2	Chl.a Productivity mg/m^2/day
10 Aug 72				
1A	1.254	0.090	6.664	0.476
1C	2.192	0.156	3.696	0.264
2A	0.692	0.049	7.196	0.514
2C	0.507	0.036	3.598	0.257
3A	4.452	0.318	8.40	0.60
3C	-	-	6.496	0.464
4A	3.066	0.219	0	0
4C	-	-	4.298	0.307
8 Sep 72				
1A	3.573	0.255	6.398	0.457
1C	0.960	0.068	1.134	0.081
2A	1.306	0.093	4.242	0.303
2C	2.453	0.175	5.614	0.401
3A	0.133	0.010	1.974	0.141
3C	0.053	0.004	1.778	0.127
4A	0.613	0.044	1.974	0.141
4C	0.454	0.032	1.834	0.131
22 Sep 72				
1A	0.053	0.004	2.128	0.152
1C	4.213	0.301	2.87	0.205
2A	0.186	0.013	3.822	0.273
2C	0.347	0.025	4.242	0.303
3A	0.186	0.013	1.232	0.088
3C	-	-	1.162	0.083
4A	0.907	0.065	3.262	0.233
4C	3.013	0.215	2.408	0.172
13 Oct 72				
1A	1.067	0.051	3.822	0.182
1C	1.441	0.067	5.061	0.241
2A	1.493	0.071	7.329	0.349
2C	1.226	0.058	13.377	0.637

Table 18. PERIPHYTON PRODUCTION
(continued)

Date & Station	Organic Wt. g/m^2	Org. Production g/m^2/day	Chl. a mg/m^2	Chl. a Productivity mg/m^2/day
13 Oct 72 (cont.)				
3A	0.800	0.038	1.113	0.053
3C	0.693	0.033	1.197	0.057
4A	0.907	0.043	2.205	0.105
4C	1.174	0.056	2.079	0.099
3 Nov 72				
1A	0.107	0.005	0.021	0.001
1C	0.267	0.013	0.735	0.035
2A	0.267	0.013	1.89	0.09
2C	1.012	0.048	41.58	1.98
3A	0.160	0.008	0.21	0.01
3C	0.107	0.005	0.504	0.024
4A	0.214	0.010	0.357	0.017
4C	0.265	0.013	0.966	0.046
30 Nov 72				
1A	0.153	0.007	0.546	0.026
1C	0.145	0.007	0.399	0.019
2A	0.195	0.009	1.596	0.076
2C	0.147	0.007	1.113	0.053
3A	0.143	0.007	0.924	0.044
3C	0.136	0.006	0.399	0.019
4A	0.187	0.009	1.281	0.061
4C	0.168	0.008	0.84	0.040
12 Jun 73				
1A	63.291	2.260	45.06	1.61
1A	56.456	2.016	34.53	1.23
1B	10.506	0.375	12.25	0.44
1B	16.456	0.588	11.34	0.41
2A	59.494	2.125	67.54	2.41
2A	50.380	1.799	44.35	1.58
2B	78.861	2.816	67.95	2.43
2B	53.797	1.921	57.32	2.05

Table 18. PERIPHYTON PRODUCTION
(continued)

Date & Station	Organic Wt. g/m^2	Org. Production g/m^2/day	Chl. a mg/m^2	Chl. a Productivity mg/m^2/day
12 Jun 73 (cont.)				
3A	119.241	4.259	74.23	2.65
3A	156.456	5.588	72.11	2.58
3B	51.392	1.835	55.59	1.99
3B	64.178	2.292	56.20	2.01
4A	86.329	3.083	60.46	2.16
4A	83.165	2.970	56.71	2.03
4B	97.342	3.477	67.54	2.41
4B	102.152	3.648	85.97	3.07
24 Jul 73 adjusted from dry weight				
1A	54.310	2.586	45.16	2.15
1A	48.500	2.309	42.73	2.03
1B	65.530	3.120	84.56	4.03
1B	87.820	4.182	76.56	3.65
2A	210.01	10.000	121.82	5.80
2A	191.73	9.130	167.29	7.97
2B	47.480	2.261	53.57	2.55
2B	37.280	1.775	65.62	3.12
3A	80.990	3.857	54.58	2.60
3A	78.800	3.752	46.48	2.21
3B	25.190	1.199	23.70	1.13
3B	23.620	1.125	32.41	1.54
4A	39.080	1.861	54.78	2.61
4A	38.300	1.824	52.35	2.49
4B	57.059	2.717	43.34	2.06
4B	56.041	2.669	60.56	2.88
11 Nov 73				
1A	757.090	9.233	652.15	7.95
1A	405.060	4.940	265.22	3.23
1B	502.658	6.130	377.92	4.61
1B	485.696	5.923	419.54	5.12

Table 18. PERIPHYTON PRODUCTION
(continued)

Date & Station	Organic Wt. g/m^2	Org. Production $g/m^2/day$	Chl. a mg/m^2	Chl. a Productivity $mg/m^2/day$
11 Nov 73 (cont.)				
2A	372.00	4.537	349.16	4.26
2A	347.82	4.242	286.99	3.50
2B	602.532	7.348	543.80	6.63
2B	844.430	10.298	336.81	4.11
3A	357.595	4.239	185.82	2.27
3A	592.152	7.221	289.82	3.53
3B	419.747	5.119	375.29	4.58
3B	47.468	5.335	409.32	4.99
4A	541.772	6.607	163.85	2.00
4A	570.380	6.956	172.35	2.10
4B	446.203	5.441	313.52	3.82
4B	475.696	5.801	145.01	1.77

throughout the summer. Collections were made when it appeared as if near maximum growth had occurred without loss of material due to buoyancy and sloughing. To compensate for these variations biomass data was calculated on a production/day basis for comparative reasons. Mean organic production during 1972-1973 is compared in Table 19. From these data it is seen that production in 1973 was greater than in 1972. On most collection dates, the organic production was less in the treatment ponds than in the control ponds: Pond 1 < Pond 2 on 66.6 percent of the collections, Pond 3 < Pond 4 on 66.6 percent of the collections, and Stress (1,3) < Control (2,4) on 66.6 percent of the collections. Mean periphyton organic production in 1972 ranged from 0.007 - 0.318 g/m^2/day whereas production in 1973 ranged from 1.310 - 6.606 g/m^2/day irrespective of stressed or control test sections.

Chlorophyll a (mg/m^2) and chlorophyll a production (mg/m^2/day) are presented in Table 18. As with mean organic production, mean chlorophyll a production by the periphyton was lower in the treatment ponds than in the control ponds on most of the collection dates (Table 19). This table is summarized as follows: Pond 1 < Pond 2 on 88.9 percent of the collection dates, Pond 3 < Pond 4 on 77.8 percent of the collection dates, Stress (1 and 3) < Control (2 and 4) on 83.4 percent of the collection dates. In summary of the four test ponds chlorophyll a production was greater in 1973 when values ranged from 0.923 - 5.228 mg/m^2/day as compared to 1972, 0.018 - 1.035 mg/m^2/day.

When the autotrophic index, $\frac{\text{organic biomass (mg/m}^2)}{\text{chlorophyll } \underline{a} \text{ (mg/m}^2)}$,

TABLE 19

Mean Organic Production*
$(g/m^2/day)$

Date	Pond 1	Pond 2	Pond 3	Pond 4
10 Aug 72	0.123	0.043	0.318	0.219
8 Sep 72	0.162	0.134	0.007	0.038
22 Sep 72	0.163	0.019	0.013	0.140
13 Oct 72	0.059	0.065	0.036	0.050
3 Nov 72	0.009	0.301	0.007	0.012
30 Nov 72	0.007	0.008	0.007	0.009
12 Jun 73	1.310	2.165	3.494	3.295
24 Jul 73	3.049	5.792	2.483	2.268
11 Nov 73	6.557	6.606	5.479	6.201

Mean Chlorophyll a Production*
$(mg/m^2/day)$

DATE	Pond 1	Pond 2	Pond 3	Pond 4
10 Aug 72	0.370	0.386	0.532	0.154
8 Sep 72	0.269	0.352	0.134	0.136
22 Sep 72	0.179	0.288	0.086	0.203
13 Oct 72	0.212	0.493	0.055	0.102
3 Nov 72	0.018	1.035	0.017	0.032
30 Nov 72	0.023	0.065	0.032	0.051
12 Jun 73	0.923	2.118	2.308	2.418
24 Jul 73	2.958	4.860	1.870	2.510
11 Nov 73	5.228	4.625	3.843	2.423

***Production is equal to the amount of biomass accrued or pigment extracted per given area divided by the number of days growing period.**

Pond 1 = non-leaded fuel stress
Pond 2 = control
Pond 3 = leaded fuel stress
Pond 4 = control

was applied to the periphyton data presented in Table 18 an interesting trend emerged. The data suggests the treatment ponds (Ponds 1 and 3) supported periphyton communities which were more heterotrophic than found in the control ponds (Ponds 2 and 4). The autotrophic index values used for these comparisons were derived from the means of organic biomass (g/m^2) after conversion to (mg/m^2) and chlorophyll a (mg/m^2) that are presented in Table 18. These mean values as well as the calculated autotrophic index values are presented in Table 20. Data in this table shows Pond 1 to have had greater mean autotrophic index values than Pond 2 in 100 percent of the collections. However, the mean autotrophic index of Pond 3 was greater than Pond 4 in only 55.5 percent of the collections. These trends are further depicted in Figures 9 and 10. Here it is also shown that Pond 3 (leaded stress pond) began as being less heterotrophic than Pond 4 (control) during the late summer and fall of 1972. As sampling progressed into November of 1972 and into 1973 a shift occurred where Pond 3 became more heterotrophic than its control (Pond 4).

Although organic production was lower in the treatment ponds than in the control ponds in 66 percent of the comparisons, these differences were not statistically significant using a paired t-test, 95 percent confidence level (Table 21). One significant variation did occur between the deep water stations of Ponds 3 and 4 during 1973.

No statistical significance was found in the differences in chlorophyll a (mg/m^2) in comparisons between stations within ponds and between composite data of pond-pairs. This held

TABLE 20

PERIPHYTON AUTOTROPHIC INDEX AS CALCULATED FROM MEAN ORGANIC BIOMASS (mg/m^2) AND MEAN CHLOROPHYLL *a* (mg/m^2)

Date	Pond	Mean Organic Weight (mg/m^2)	Mean Chlorophyll (mg/m^2)	Autotrophic Index
10 Aug 72	1	1723.0	5.18	333
	2	599.5	5.40	111
	3	4452.0	7.45	598
	4	3066.0	2.15	1426
8 Sep 72	1	2266.5	3.77	601
	2	1879.5	4.93	381
	3	93.0	1.88	49
	4	533.5	1.90	281
22 Sep 72	1	2133.0	2.50	853
	2	266.5	4.03	66
	3	186.0	1.20	155
	4	1960.0	2.84	690
13 Oct 72	1	1254.0	4.44	282
	2	1359.5	10.35	131
	3	746.5	1.16	644
	4	1040.5	2.14	486
3 Nov 72	1	187.0	0.38	492
	2	639.5	21.74	29
	3	133.5	0.36	371
	4	239.5	0.66	363
30 Nov 72	1	149.0	0.47	317
	2	171.0	1.35	127
	3	139.5	0.66	211
	4	177.5	1.06	167
12 Jun 73	1	36,677.3	25.80	1422
	2	60,633.0	59.29	1023
	3	97,816.8	64.53	1516
	4	92,247.0	67.67	1363
24 Jul 73	1	64,040.0	62.25	1029
	2	31,233.5	102.08	306
	3	52,150.0	39.29	1327
	4	47,620.0	52.76	903
11 Nov 73	1	537,626.0	428.71	1254
	2	379,736.0	379.19	1001
	3	451,740.5	315.06	1434
	4	508,512.8	198.68	2559

TABLE 21
PERIPHYTON STATISTICS
Paired t-test - 95 percent confidence level

1972

Parameter	Test Ponds	df	$\bar{Y}$	$S_{\bar{Y}}$	$\bar{X}$	$S_{\bar{X}}$	F value	t_s	t_s^2	sig.
Organic Production g/m^2/day	1 v 2 composite	9	0.07	0.08	0.06	0.05	7.21	-0.66	0.44	
	1 v 2 shallow	4	0.08	0.10	0.05	0.04	12.2	-1.03	1.06	
	1 v 2 deep	4	0.06	0.06	0.07	0.07	12.2	0.07	< 0.01	
	3 v 4 composite	9	0.04	0.10	0.05	0.06	7.21	0.44	0.20	
	3 v 4 shallow	5	0.07	0.12	0.06	0.08	10.0	-0.03	< 0.01	
	3 v 4 deep	3	0.01	0.01	0.03	0.02	17.4	2.49	6.20	
Chlorophyll a Production mg/m^2/day	1 v 2 composite	9	0.19	0.17	0.48	0.56	7.21	1.53	2.34	
	1 v 2 shallow	4	0.26	0.20	0.30	0.16	12.2	0.81	0.66	
	1 v 2 deep	4	0.13	0.12	0.67	0.76	12.2	1.49	2.22	
	3 v 4 composite	10	0.10	0.13	0.12	0.09	6.94	0.99	0.98	
	3 v 4 shallow	4	0.07	0.05	0.11	0.08	12.2	1.65	2.72	
	3 v 4 deep	5	0.13	0.17	0.13	0.10	10.0	0.10	0.01	
Autotrophic Index	1 v 2	5	479.67	219.68	140.83	124.07	10.0	-3.38	11.42	*
	3 v 4	5	338.00	243.09	566.83	456.72	10.0	1.48	2.18	

Correlation Coefficient	Pond	V	Critical Value (95%)	Correlation Coefficient	sig.
Organic Biomass v Chlorophyll a	1	8	0.726	0.759	*
	2	9	0.697	0.511	
	3	8	0.726	0.956	*
	4	7	0.758	0.803	*

1973

Parameter	Test Ponds	df	$\bar{Y}$	$S_{\bar{Y}}$	$\bar{X}$	$S_{\bar{X}}$	F value	t_s	t_s^2	sig.
Organic Production g/m^2/day	1 v 2 composite	11	3.64	2.56	4.86	3.39	6.72	1.20	1.43	
	1 v 2 shallow	5	3.89	2.83	5.31	3.49	10.0	0.73	0.53	
	1 v 2 deep	5	3.38	2.51	4.40	3.57	10.0	1.09	1.19	
	3 v 4 composite	11	3.82	1.89	3.92	1.80	6.72	0.21	0.05	
	3 v 4 shallow	5	4.82	1.35	3.88	2.31	10.0	-1.28	1.64	
	3 v 4 deep	5	2.82	1.92	3.96	1.35	10.0	4.76	22.61	*
Chlorophyll a Production mg/m^2/day	1 v 2 composite	11	3.04	2.20	3.87	1.99	6.72	1.18	1.39'	
	1 v 2 shallow	5	3.03	2.50	4.25	2.34	10.0	0.91	0.83	
	1 v 2 deep	5	3.04	2.09	3.48	1.70	10.0	0.76	0.58	
	3 v 4 composite	11	2.67	1.16	2.45	0.58	6.72	-0.65	0.42	
	3 v 4 shallow	5	2.64	0.47	2.23	0.26	10.0	-1.70	2.89	
	3 v 4 deep	5	2.71	1.65	2.67	0.75	10.0	0.06	< 0.01	
Autotrophic Index	1 v 2	2	1235.00	192.18	776.67	407.76	38.5	-3.30	10.89	
	3 v 4	2	1425.67	94.78	1608.33	854.83	38.5	0.382	0.146	

Correlation Coefficient	Pond	V	Critical Value (95%)	Correlation Coefficient	sig.
Organic Biomass v Chlorophyll a	1	10	0.671	0.993	*
	2	10	0.671	0.973	*
	3	10	0.671	0.909	*
	4	10	0.671	0.833	*

1972

Parameter	Test Ponds	df	$\bar{Y}$	$S_{\bar{Y}}$	$\bar{X}$	$S_{\bar{X}}$	F value	t_s	t_s^2
Richness	1 v 2 composite	11	2.33	0.50	2.37	0.50	6.72	0.24	0.06
	3 v 4 composite	11	1.94	0.35	2.14	0.48	6.72	1.08	1.17
Diversity	1 v 2 composite	11	0.20	0.16	0.15	0.06	6.72	-1.46	2.13
	3 v 4 composite	11	0.14	0.08	0.15	0.06	6.72	0.22	0.05

FIGURE 9. Periphyton Autotrophic Index – Ponds 1 and 2, 1972 and 1973

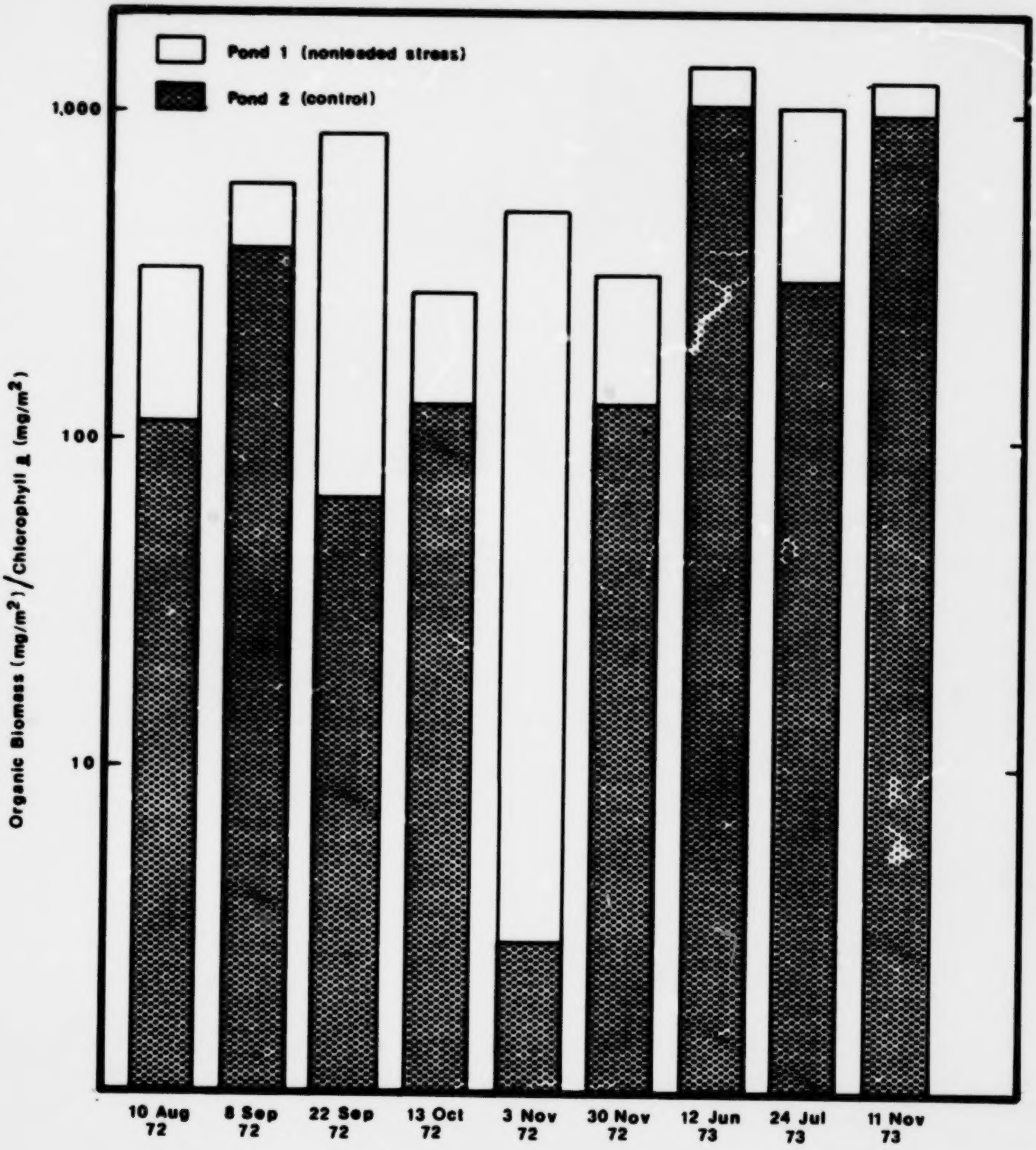
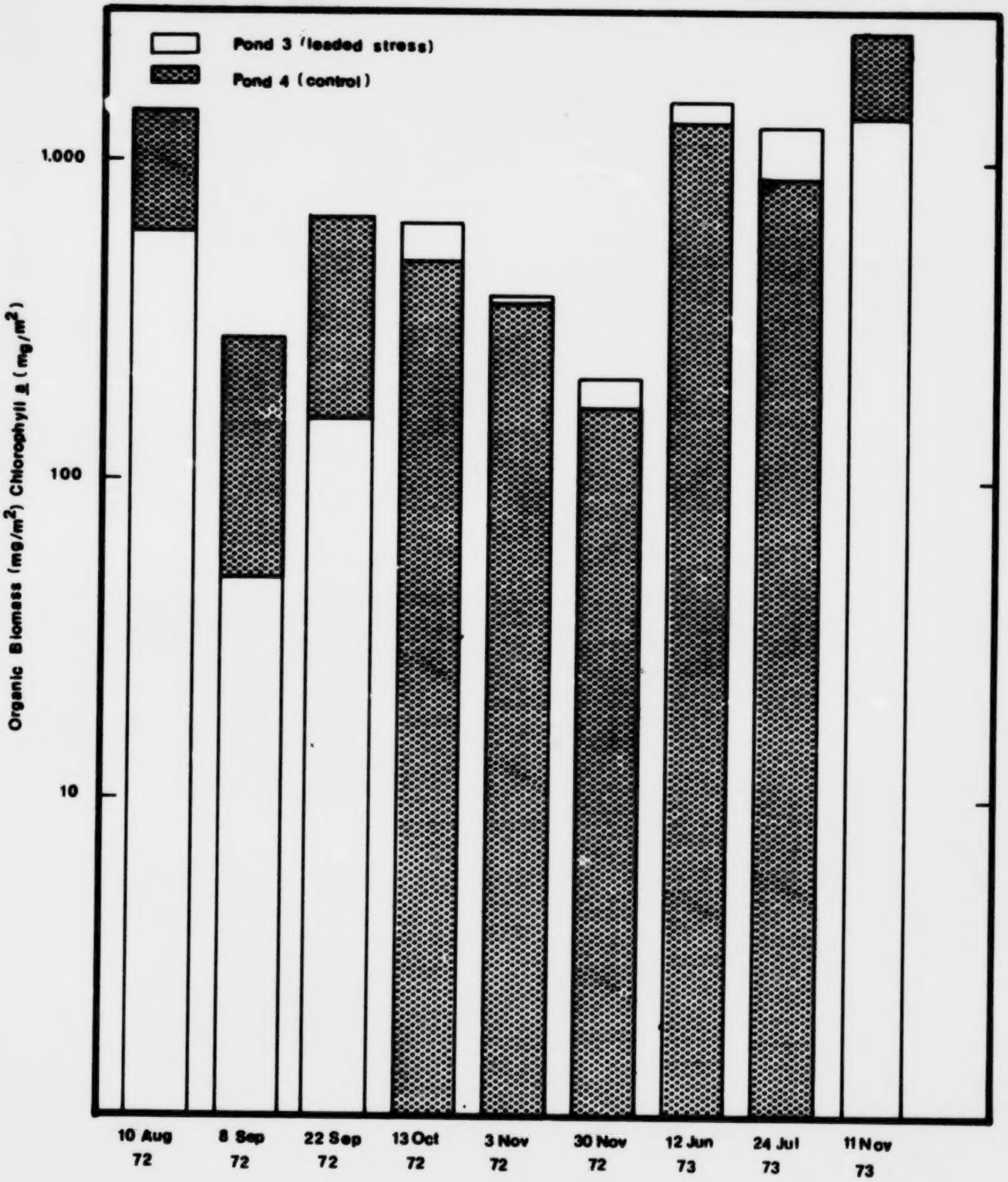


FIGURE 10. Periphyton Autotrophic Index - Ponds 3 and 4, 1972 and 1973



true for both the 1972 and 1973 collections.

The use of correlation coefficient to compare organic biomass with chlorophyll a mass showed significant correlation in Ponds 1, 3 and 4 (1972) and in all test ponds during 1973.

The autotrophic index data suggests that the treatment ponds supported more heterotrophic periphyton communities than the control ponds. Weber (47) has used this index to indicate trophic status or toxicity of natural water. Autotrophic index values greater than 100 suggest heterotrophic communities comprised of bacteria, protozoa, and other nonalgal (nonchlorophyllous) species. This is based on an increase of organic material which increases the available food sources for heterotrophic species. Data from the outboard engine experiments indicate that Pond 1 (non-leaded stress pond) was significantly more heterotrophic than its adjacent control (Pond 2) during 1972 (Table 21). There was no significance in the variations observed between the autotrophic index of Pond 3 (leaded stress) and Pond 4 (control) during 1972 and 1973, nor between Ponds 1 and 2 during 1972. Significance was determined by the paired-t test, 95 percent level of confidence.

The conclusions based upon these data are not definitive at this point in time. After analysis of periphyton data in 1972 the speculation was made that the treatment ponds supported periphyton associations comprised of bacteria which did not occur in the control ponds. It was felt that outboard engine emissions may have provided sufficient hydrocarbon material thereby creating a nutrient enrichment media, i.e., the treatment ponds would have more carbon substrates for bacterial degradation. It this were true the organic biomass in the treatment ponds may be the result of heterotrophic species (bacteria) rather than of autotrophic species (diatoms). The autotrophic index indicates a more heterotrophic periphyton community in the treatment ponds as compared to the control ponds but this has yet to be quantified in terms of bacteria and fungi. There were no significant differences in the diatom associations between ponds. At the present time a microbiological study is being completed which will be related to the autotrophic index and to hydrocarbon concentrations in the periphyton which is also near completion. After compilation of the forthcoming data more definite conclusions will be available.

Phytoplankton

Species Abundance and Occurrence - Phytoplankton samples examined in 1971 represented 10 dates, August 14 - November 2. Species occurrence was similar in the four test ponds: Pond 1 (non-leaded stress) - 46 species, Pond 2 (control) - 40 species, Pond 3 (leaded stress) - 39 species, and Pond 4 (control) - 39 species (Table 22). Species occurring exclusively in one pair of ponds included *Volvox aureus* (Ponds 1 and 2), *Fragilaria crotonensis* (Ponds 1 and 2), and *Cyclotella comta* var. *oligactis* (Ponds 1 and 2), the latter being quantitatively important. All four test ponds were qualitatively similar during the fall, 1971, collecting period.

TABLE 22

Species and Occurrence of Phytoplankton-1971	Pond #			
	1	2	3	4
Ceratium hirundinella (O.F. Muell.) Dujardin	x	x	x	x
Rhodomonas minuta var. *nannoplanctica* Skuja	x	x	x	x
Cryptomonas erosa Ehrenberg	x	x	x	x
Cryptomonas erosa var. *reflexa* Marsson	x	x	x	x
Cryptomonas ovata Ehrenberg	x	x	x	x
Cryptomonas ovata var. *curvata* 'Lemm.	x	x	x	x
Dinobryon divergens Imhof	x	x	x	x
Dinobryon sociale var. *americanum* (Brunnth.) Bachm.	x	x	x	x
Dinobryon bavaricum Imhof	x	x	x	x
Mallomonas akrokomos Ruttner	x	x	x	x
Kephyrion spirale (Lack.) Conrad	x	x	x	x
Kephyrion ovale (Lackey) H.-P.	x	x	x	x
Hyalobryon Leickii Gessner	x	x	x	x
Hyalobryon ramosum Lauterborn	x			
Volvox globator Linnaeus	x	x		x
Volvox aureus Ehrenberg	x	x		
Sphaerocystis schroeteri Chodat	x	x	x	x
Ankistrodesmus falcatus (Corda) Ralfs	x	x	x	x
Elaktothrix gelatinosa Wille	x	x	x	x
Pediastrum tetras (Ehrenb.) Ralfs	x	x		x
Pediastrum boryanum (Turp.) Meneghini				x
Tetraëdron minimum (A.Braun) Hansgirg	x	x	x	
Tetraëdron caudatum (Corda) Hansgirg	x			
Crucigenia apiculata (Lemm.) Schmidle	x			
Crucigenia tetrapedia (Kirch.) West and West	x			
Scenedesmus bijuga var. *alternans* (Reinsch) Hansgirg	x	x	x	x
Scenedesmus arcuatus Lemmermann				
Scenedesmus denticulatus Lagerheim	x	x	x	x
Scenedesmus dimorphus (Turp.) Kuetzing	x	x	x	x
Scenedesmus quadricauda (Turp.) de Brébisson	x	x	x	x
Dactylococcus infusonium Naegeli			x	
Geminella interrupta (Turp.) Lagerheim				x
Desmatractum sp.	x			
Closterium venus Kuetzing	x	x	x	x
Trachelomonas volvocina Ehrenberg	x	x	x	x
Ochromonas sphagnalis Conrad			x	
Chrysapsis sagene Pascher			x	

TABLE 22(continued)

Species and Occurrence 1971	Pond #			
	1	2	3	4
Chroococcus turgidus (Kuetz.) Naegeli		x	x	x
Anabaena inaequalis (Kuetz.) Bornet and Flahault			x	
Achnanthes minutissima (Kuetz.) var. *minutissima*	x	x	x	x
Fragilaria crotonensis Kitton	x	x		
Synedra ulna (Nitz.) Ehr. var *ulna*	x	x	x	x
Synedra delicatissima W. Sm. var *delicatissima*	x	x	x	x
Synedra tenera W. Sm. var *tenera*	x	x	x	x
Gyrosigma sp.	x			
Rhopalodia gibba (Kuetzing) Mueller	x	x	x	x
Epithemia zebra (Ehrenberg) Kuetzing	x	x	x	x
Cymbella cistula (Hemprich) Grunow	x	x	x	x
Meridion circulare (Greville) C.A. Agardh	x			
Gomphonema acuminatum var. *coronatum* (Ehrenberg) Rabenhorst	x	x	x	x
Gomphonema constrictum Ehrenberg	x	x	x	x
Gomphonema gracile var. *naviculoides* (W.Sm.) Grun.	x	x	x	x
Gomphonema lanceolatum Ehrenberg	x	x	x	x
Cyclotella comta var. *oligactis* (E.) Grun.	x	x		
Total Occurrence:	46	40	39	39

The occurrence of dominant species was similar in the four test ponds although abundance and succession were asynchronous between ponds (Figures 11 and 12). Ceratium hirundinella was abundant in Ponds 1 and 2 and also in Ponds 3 and 4 but during a different time period. Dinobryon sociale and D. bavaricum composed a late fall bloom which was strongly evident in Ponds 1, 2, and 3 but not as evident in Pond 4. Other species, e.g., Rhodomonas minuta and Cryptomonas erosa, were present in varying numbers throughout the fall in all four test ponds.

Biomass data, presented in Appendix C-20 and Figures 13 through 18 are categorized as euplankters, free-living organisms of open water, and tychoplankters, unattached organisms associated among algal mixtures and weed beeds, Prescott(94). All flagellated species, unicellular and colonial green algae, and the centric diatoms have been included as euplankton while the pennate diatoms are included as tychoplankton. Such classification may not be absolute, however, it is useful when attempting to evaluate the sudden changes in total phytoplankton biomass due to abnormally large numbers of periphytic species.

Plots of total biomass (Figures 13 and 14) show that the test ponds varied as pairs, with Ponds 1 and 2 having greatest biomass in mid-September and mid-October while Ponds 3 and 4 had greatest biomass in late August. A difference occurred between Ponds 3 and 4 during October when Pond 4 (control) had consistently greater total biomass than Pond 3 (leaded gas stress). Reference to Figures 15 and 16 indicates that tychoplankton contributed

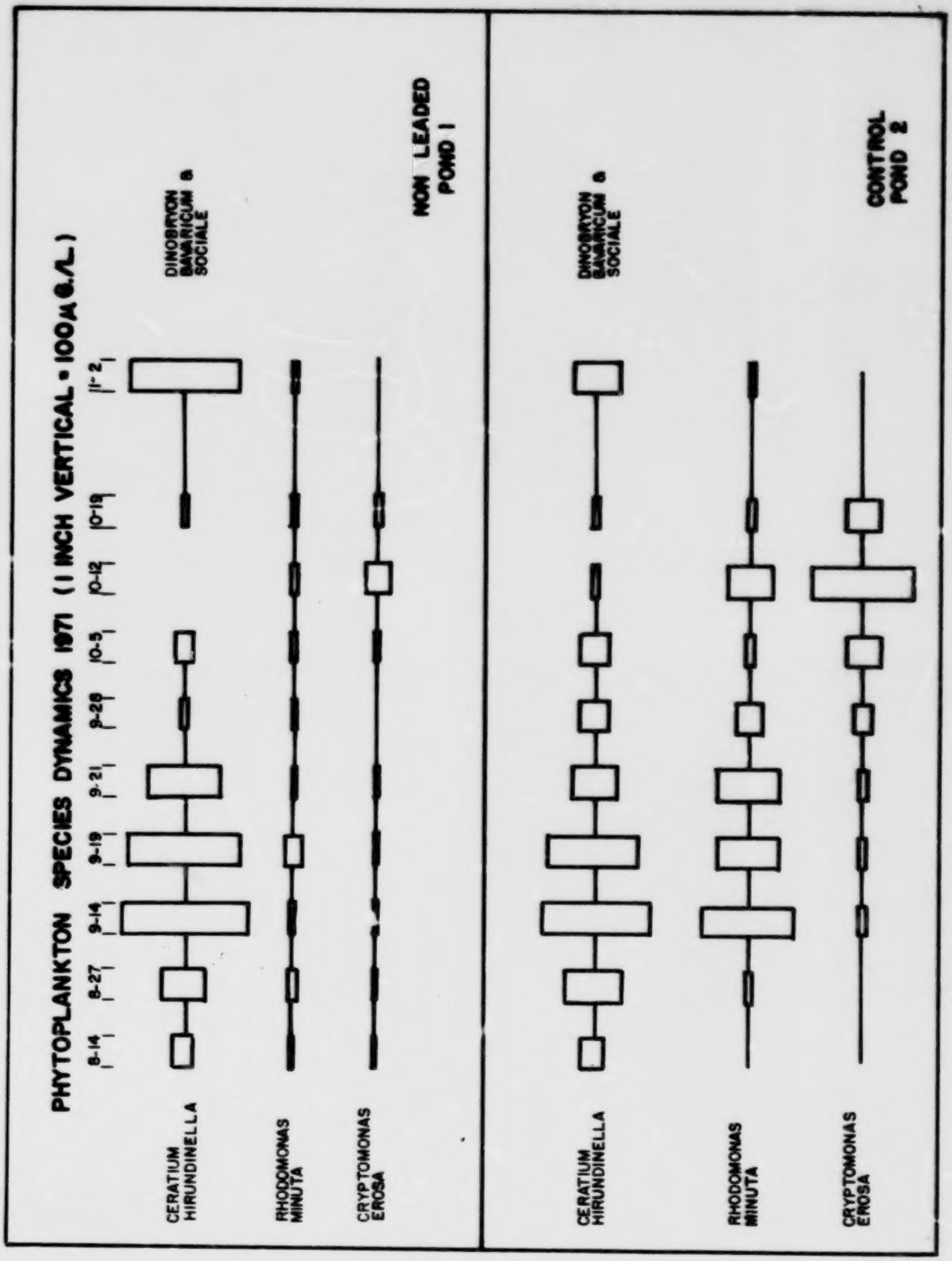

PHYTOPLANKTON SPECIES DYNAMICS 1971 (1 INCH VERTICAL = 100μ G./L.)
8-14
8-27
9-14
9-19
9-21
9-28
10-5
10-12
10-19
11-2
CERATIUM HIRUNDINELLA
DINOBRYON BAVARICUM & SOCIALE
RHODOMONAS MINUTA
CRYPTOMONAS EROSA
NON LEADED POND 1
CERATIUM HIRUNDINELLA
DINOBRYON BAVARICUM & SOCIALE
RHODOMONAS MINUTA
CRYPTOMONAS EROSA
CONTROL POND 2

FIGURE 11

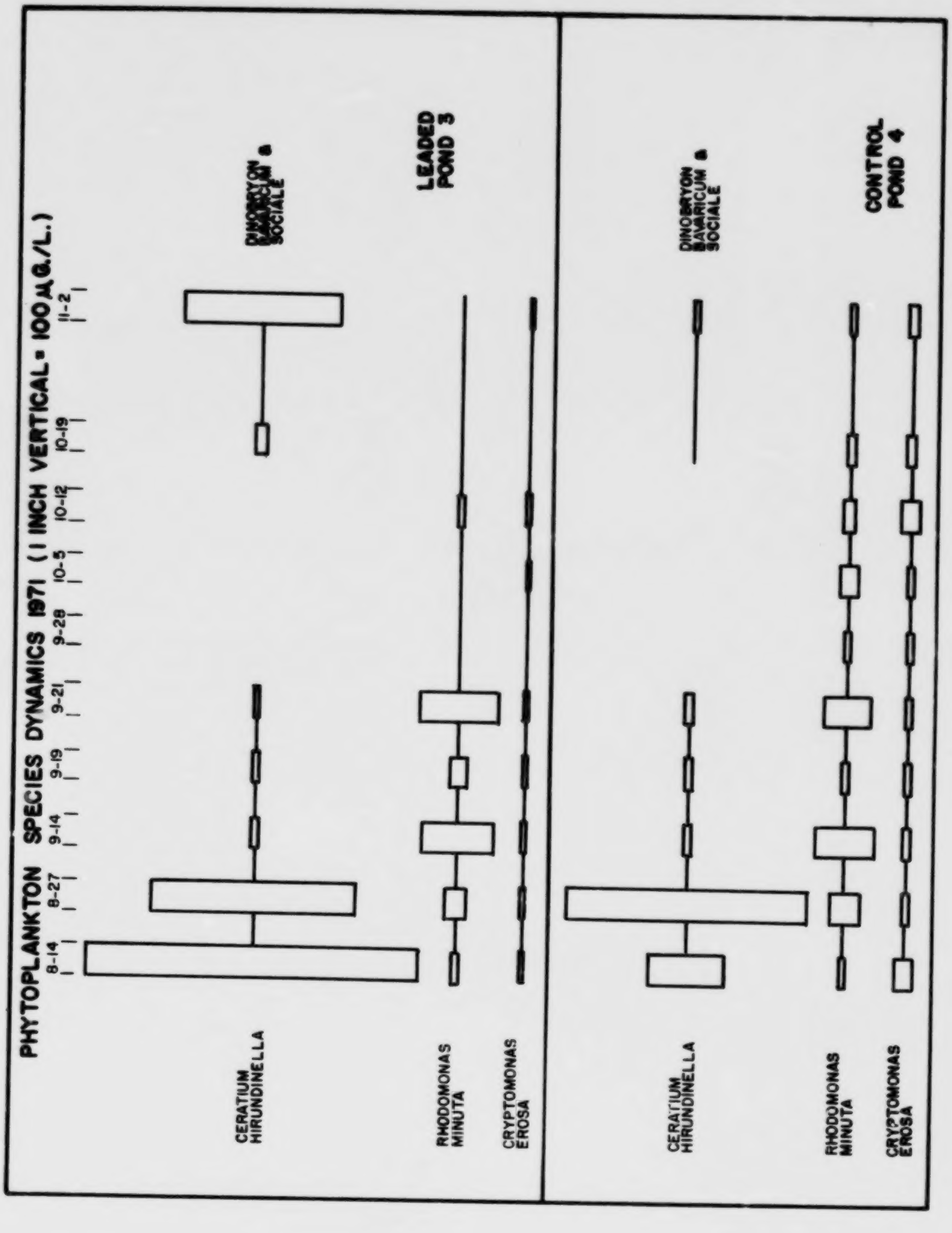

PHYTOPLANKTON SPECIES DYNAMICS 1971 (1 INCH VERTICAL = 100 µG./L.)
8-14
8-27
9-14
9-19
9-21
9-28
10-5
10-12
10-19
11-2
CERATIUM HIRUNDINELLA
DINOBRYON BAVARICUM & SOCIALE
RHODOMONAS MINUTA
CRYPTOMONAS EROSA
LEADED POND 3
CERATIUM HIRUNDINELLA
DINOBRYON BAVARICUM & SOCIALE
RHODOMONAS MINUTA
CRYPTOMONAS EROSA
CONTROL POND 4

FIGURE 12

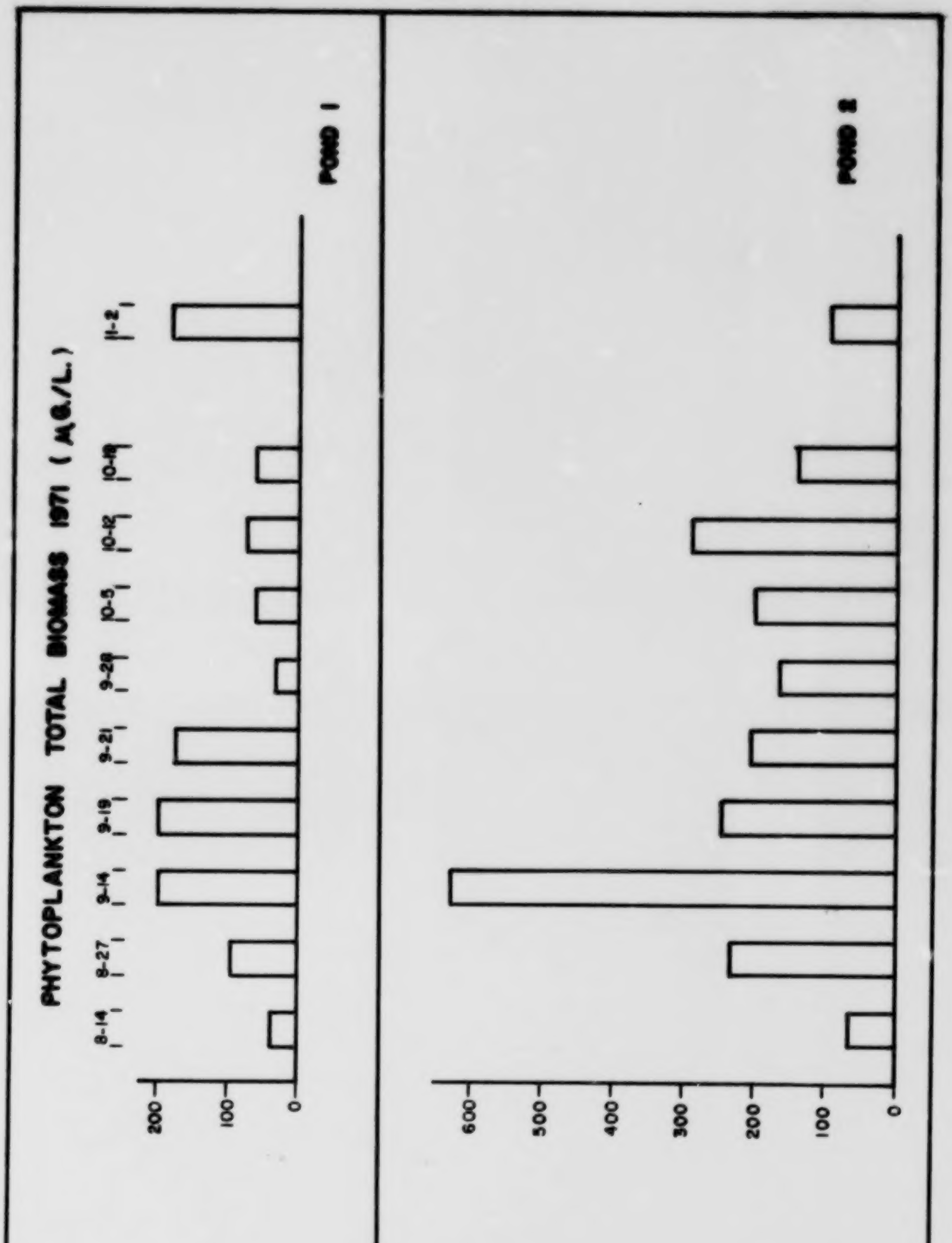
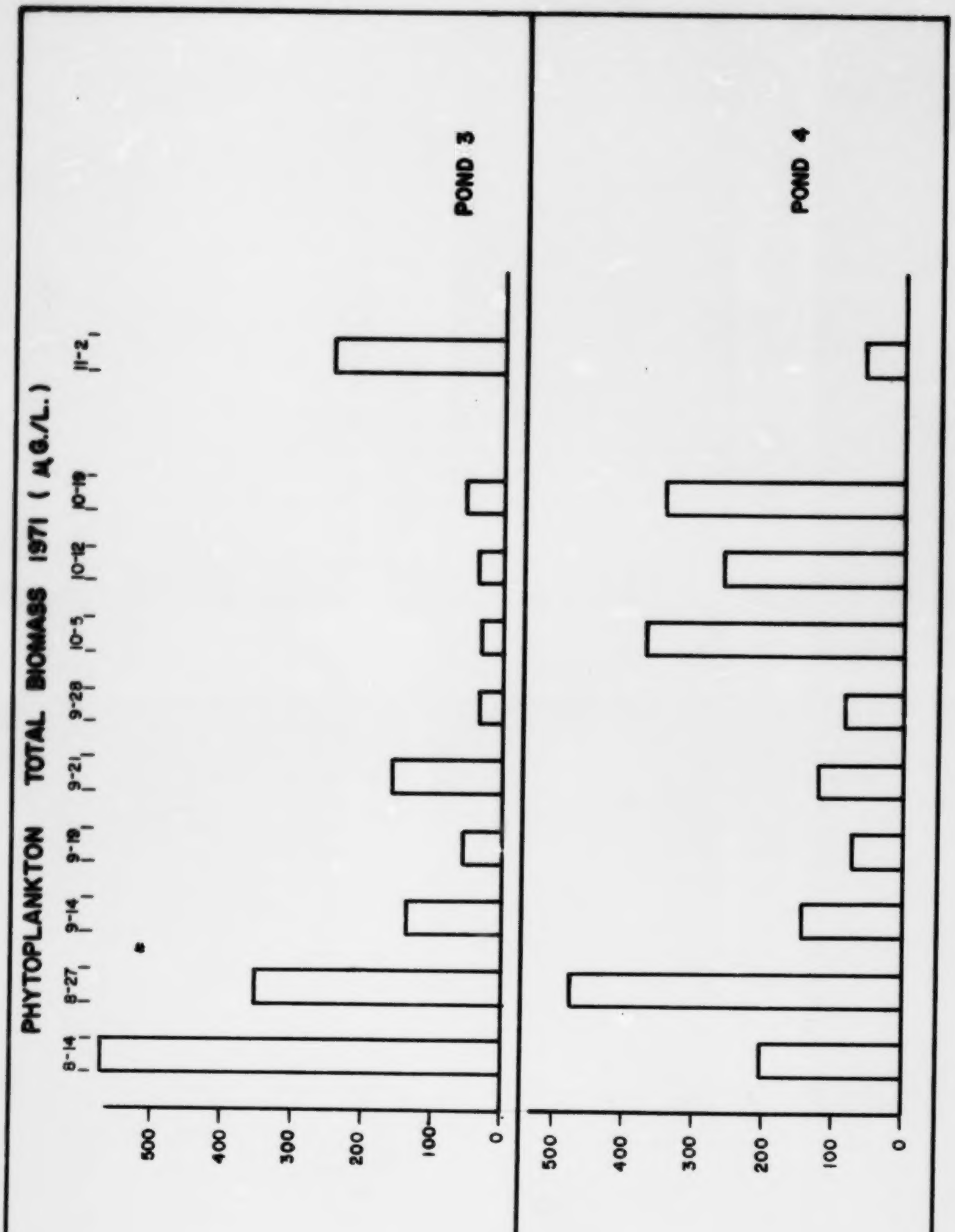

PHYTOPLANKTON TOTAL BIOMASS 1971 (μG./L.)
8-14
8-27
9-14
9-19
9-21
9-28
10-5
10-12
10-19
11-2
200
100
0
POND I
600
500
400
300
200
100
0
POND II

FIGURE 13



PHYTOPLANKTON TOTAL BIOMASS 1971 (μG./L.)

POND 3

POND 4

FIGURE 14

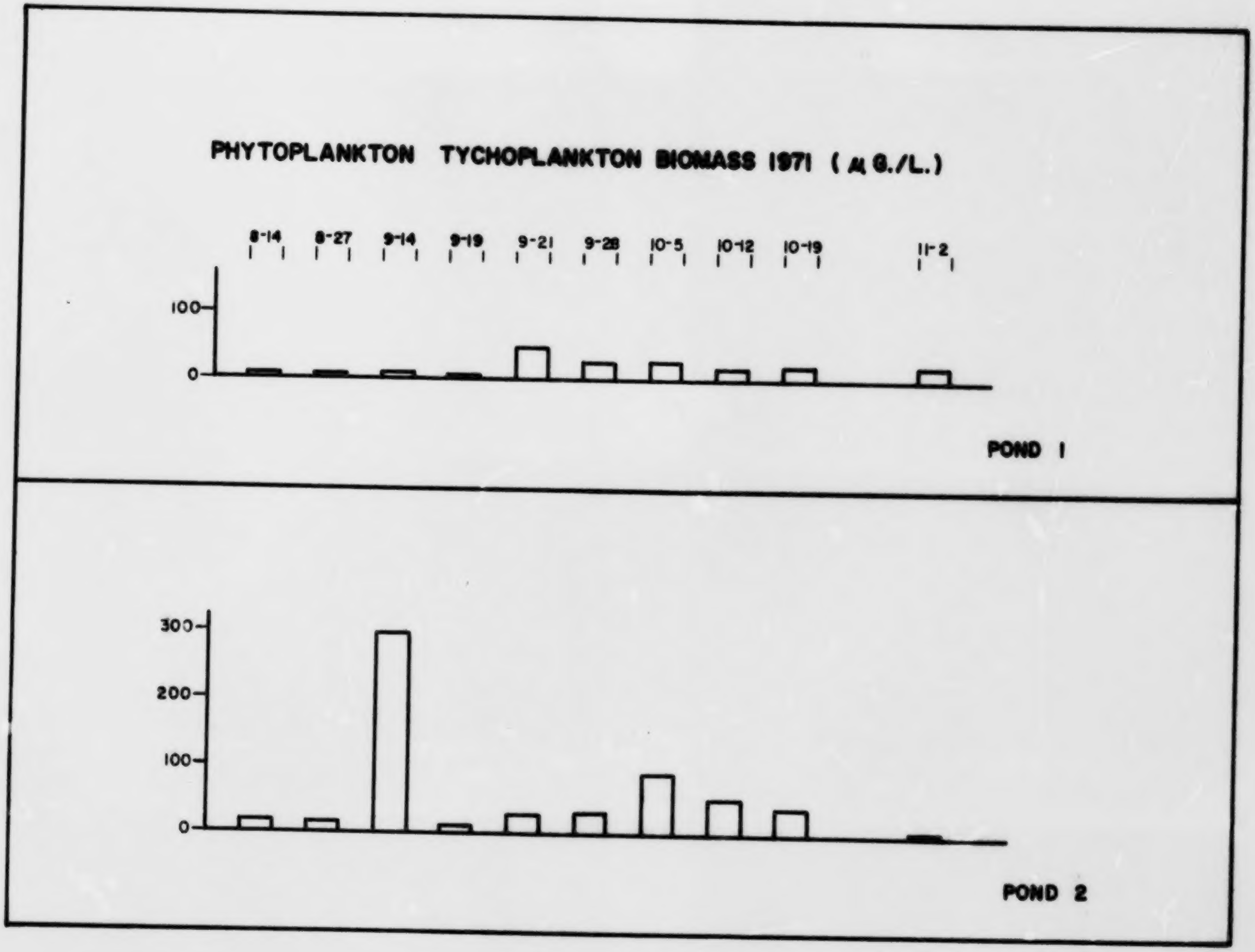

PHYTOPLANKTON TYCHOPLANKTON BIOMASS 1971 (μG./L.)

FIGURE 15

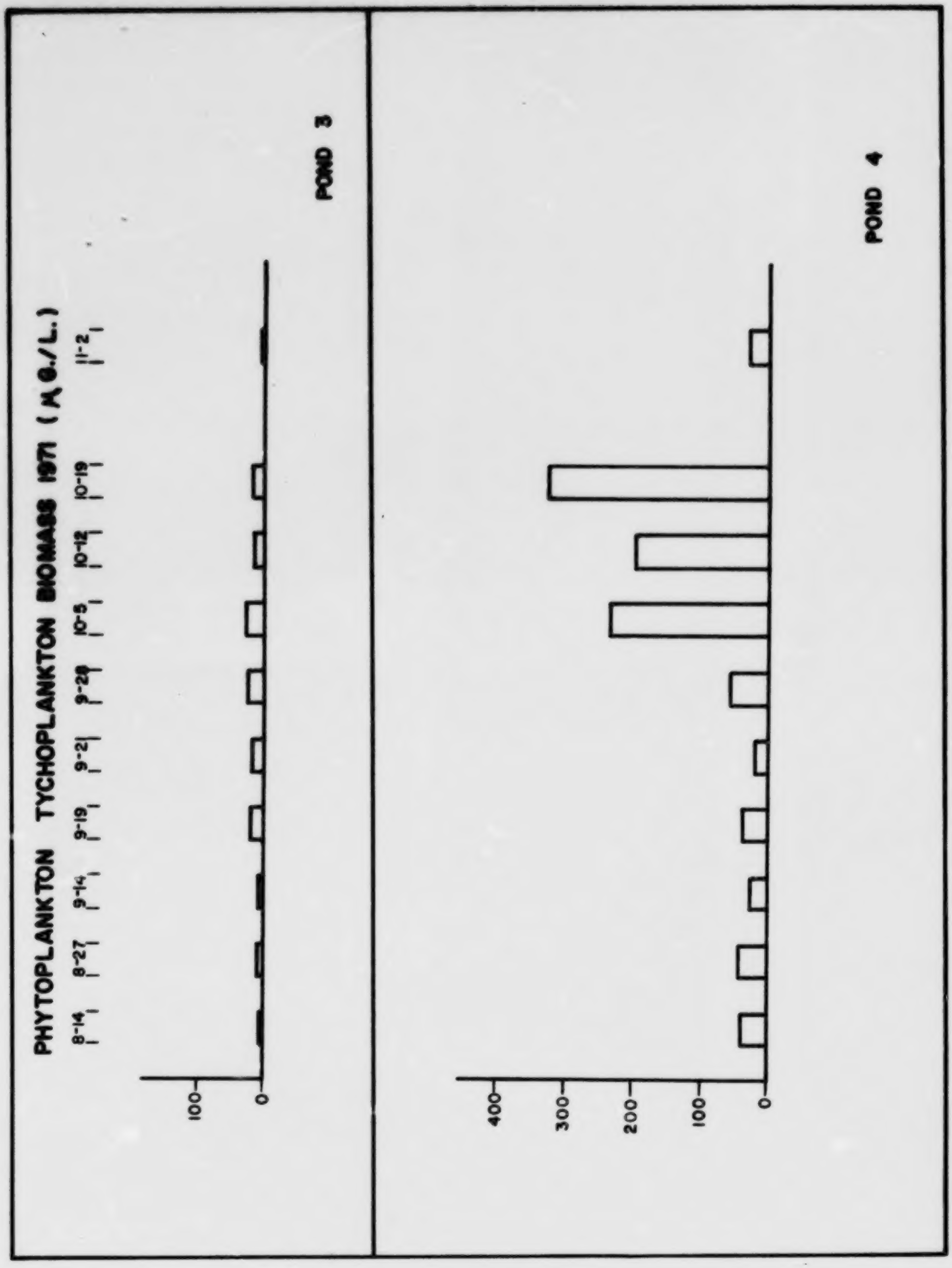

PHYTOPLANKTON TYCHOPLANKTON BIOMASS 1971 (μG./L.)
8-14
8-27
9-14
9-19
9-21
9-28
10-5
10-12
10-19
11-2
100
0
POND 3
400
300
200
100
0
POND 4

FIGURE 18

most of the biomass in Pond 4 during that period, and a comparison on the basis of euplankton shows much smaller differences (Figures 17 and 18). Tychoplankton was consistently more abundant in Ponds 2 and 4 (controls) than in Ponds 1 and 3 (stressed).

During 1972 and early 1973, the trends of the phytoplankton populations were similar and the test ponds again varied as pairs, i.e., Pond 1 similar to Pond 2 and likewise Pond 3 to Pond 4. As indicated by Table 23 and Figures 19 and 20, shifts in total population (no./ml) were parallel in pond-pairs with occassional lag periods noticeable. Pond 1 and 2 were very similar in terms of total numbers of individuals (no./ml) with Pond 1 (non-leaded stress) most often dominating over its control (Pond 2). Ponds 3 and 4 were likewise similar and parallel in terms of total numbers of individuals with definite lag periods being obvious and Pond 4 (control) most often dominating over its leaded stress counterpart (Pond 3). Furthermore, as pairs Ponds 1 and 2 most often had fewer total organisms/ml than did Ponds 3 and 4 (Figures 19 and 20).

With reference to dominant groups of species Ponds 1 and 2 were more stable than Ponds 3 and 4. The green algae (Chlorophyta) were dominant in Ponds 1 and 2 with few exceptions (Appendix C-21) and Figure 21). In Ponds 3 and 4 the green algae were usually dominant but were often replaced by the diatoms (Bacillariophyta) as the dominant or co-dominant group (Appendix C-21 and Figure 22). The blue-green algae (Cyanophyta), although not displayed in graphic form, were abundant to dominant during certain time periods (Appendix C-21). In Ponds 1 and 2 the blue-green group was quantitatively equal to the Chrysophyta and Bacillariophyta during August, 1972: all being less

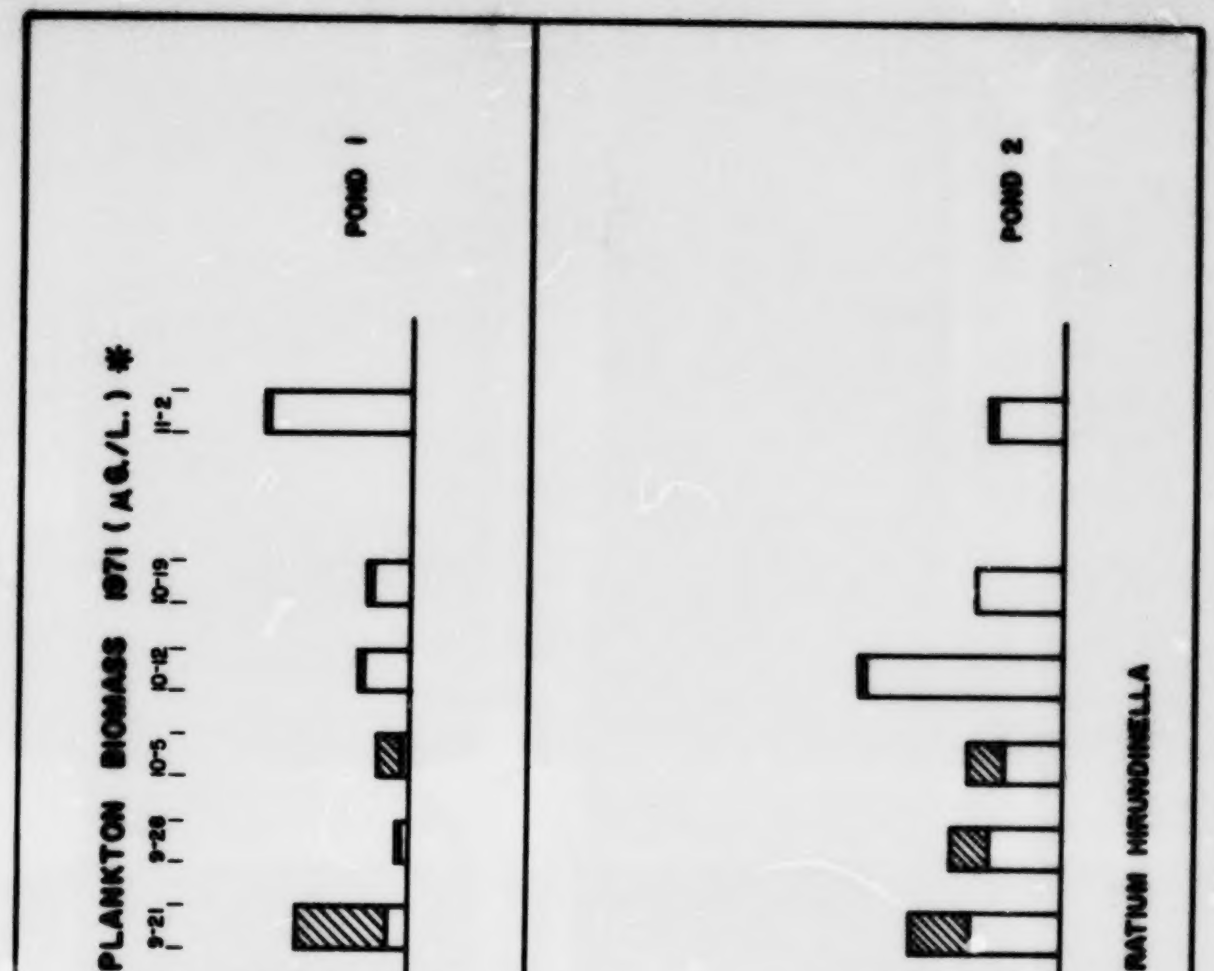

PHYTOPLANKTON EUPLANKTON BIOMASS 1971 (µG./L.) *
8-14
8-27
9-14
9-19
9-21
9-28
10-5
10-12
10-19
11-2
200
100
0
POND 1
500
400
300
200
100
0
POND 2
* SHADED PORTION CONTRIBUTED BY CERATIUM HIRUNDINELLA

FIGURE 17

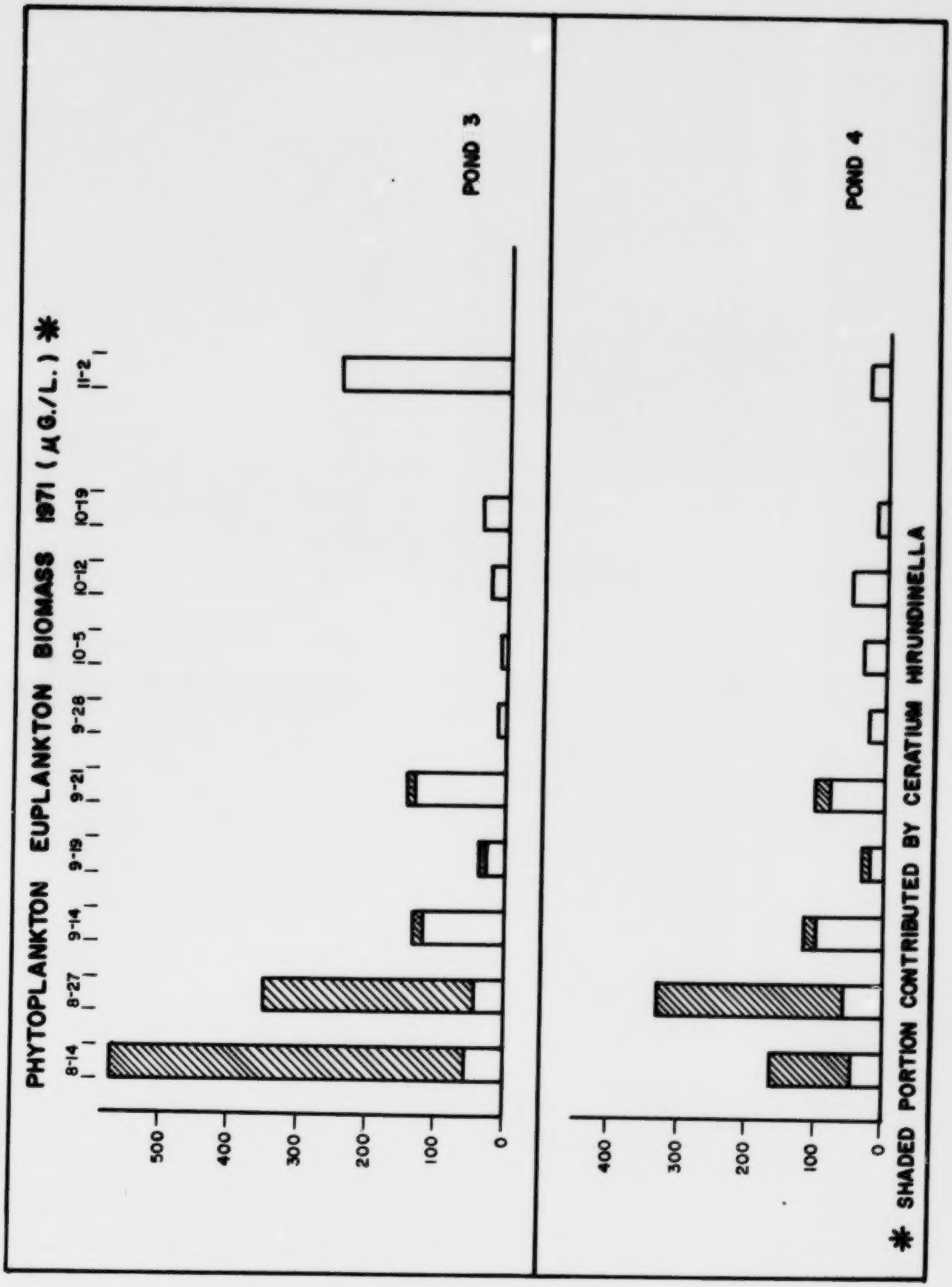

PHYTOPLANKTON EUPLANKTON BIOMASS 1971 (μG./L.) *
8-14
8-27
9-14
9-19
9-21
9-28
10-5
10-12
10-19
11-2
500
400
300
200
100
0
POND 3
400
300
200
100
0
POND 4
* SHADED PORTION CONTRIBUTED BY CERATIUM HIRUNDINELLA

FIGURE 18

TABLE 23

PHYTOPLANKTON SPECIES RICHNESS MEASUREMENTS

Date	Pond No.	Total Species	Total Individuals	Species Richness ($S-1/\ln N$)	Species Richness ($S/\sqrt{N}$)
28 Jul 72	1	41	6740	4.50	0.50
	2	26	5167	2.90	0.36
	3	35	13,806	3.60	0.30
	4	34	12,622	3.50	0.30
4 Aug 72	1	54	9432	5.80	0.56
	2	43	5457	4.90	0.58
	3	47	49,022	4.30	0.21
	4	51	45,739	4.70	0.24
11 Aug 72	1	53	20,992	5.23	0.37
	2	54	15,166	5.51	0.44
	3	48	15,180	4.88	0.39
	4	53	31,697	5.02	0.30
25 Aug 72	1	42	14,894	4.27	0.34
	2	43	9507	4.59	0.44
	3	47	19,811	4.65	0.33
	4	45	14,244	4.60	0.38
14 Sep 72	1	29	3882	3.39	0.47
	2	35	4069	4.09	0.55
	3	30	27,457	2.84	0.18
	4	35	11,158	3.65	0.33
21 Sep 72	1	44	9050	4.72	0.46
	2	43	6976	4.75	0.51
	3	46	62,641	4.07	0.18
	4	47	34,863	4.40	0.25
2 Oct 72	1	32	6661	3.52	0.39
	2	31	3600	3.66	0.52
	3	47	20,750	4.63	0.33
	4	36	41,001	3.30	0.18
6 Oct 72	1	37	6852	4.08	0.45
	2	33	5075	3.75	0.46
	3	34	11,842	3.52	0.31
	4	36	20,264	3.53	0.25
17 Oct 72	1	35	9644	3.71	0.36
	2	31	15,703	3.11	0.25
	3	38	9174	4.06	0.40
	4	41	15,749	4.14	0.33

TABLE 23

PHYTOPLANKTON SPECIES RICHNESS MEASUREMENTS
(continued)

Date	Pond No.	Total Species	Total Individuals	Species Richness $(S-1/\ln N)$	Species Richness $(S/\sqrt{N})$
24 Oct 72	1	29	8099	3.11	0.32
	2	27	11,067	2.79	0.26
	3	42	7063	4.63	0.50
	4	31	9138	3.29	0.32
25 Apr 73	1	21	11,893	2.13	0.19
	2	16	7705	1.68	0.18
	3	19	20,184	1.82	0.13
	4	19	24,103	1.78	0.12
14 May 73	1	23	5857	2.54	0.30
	2	21	7118	2.25	0.25
	3	24	10,947	2.47	0.23
	4	29	20,182	2.82	0.20
21 May 73	1	21	11,408	2.14	0.20
	2	20	14,867	1.98	0.16
	3	16	7027	1.69	0.19
	4	26	7613	2.80	0.30
29 May 73	1	22	14,641	2.19	0.18
	2	18	8109	1.89	0.20
	3	20	16,263	1.96	0.16
	4	20	5990	2.18	0.26
5 Jun 73	1	16	4864	1.77	0.23
	2	17	5946	1.84	0.22
	3	18	13,899	1.78	0.15
	4	23	43,003	2.06	0.11
8 Jun 73	1	25	17,298	2.46	0.19
	2	26	14,392	2.61	0.22
	3	23	32,099	2.12	0.13
	4	24	27,593	2.25	0.14
14 Jun 73	1	28	25,543	2.66	0.18
	2	29	11,665	2.99	0.27
	3	24	34,280	2.20	0.13
	4	29	10,600	3.02	0.28

FIGURE 19. Total Phytoplankton (numbers/ml.) Ponds 1 and 2, 1972-1973

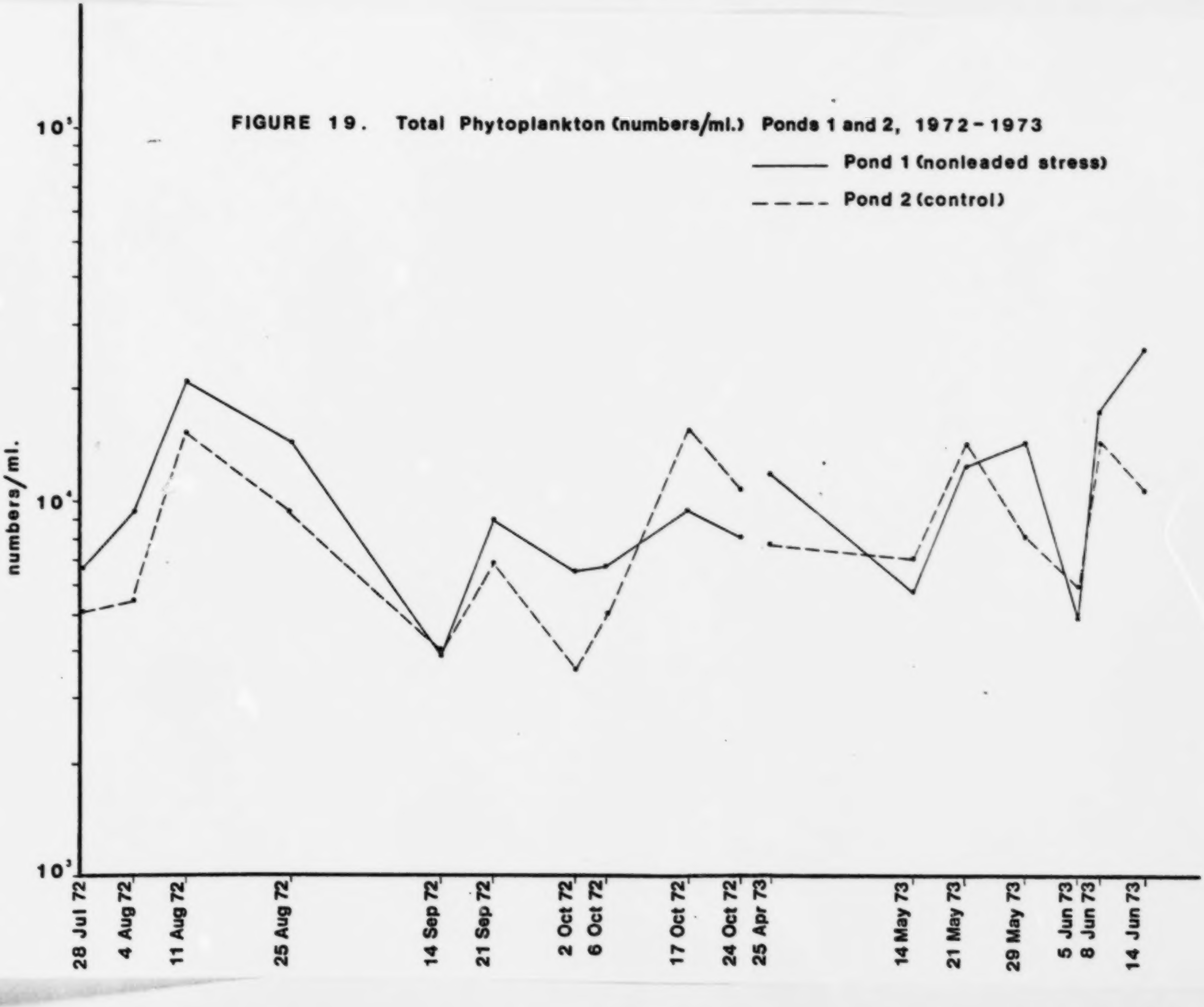


FIGURE 20. Total Phytoplankton (numbers/ml.) Ponds 3 and 4, 1972 - 1973

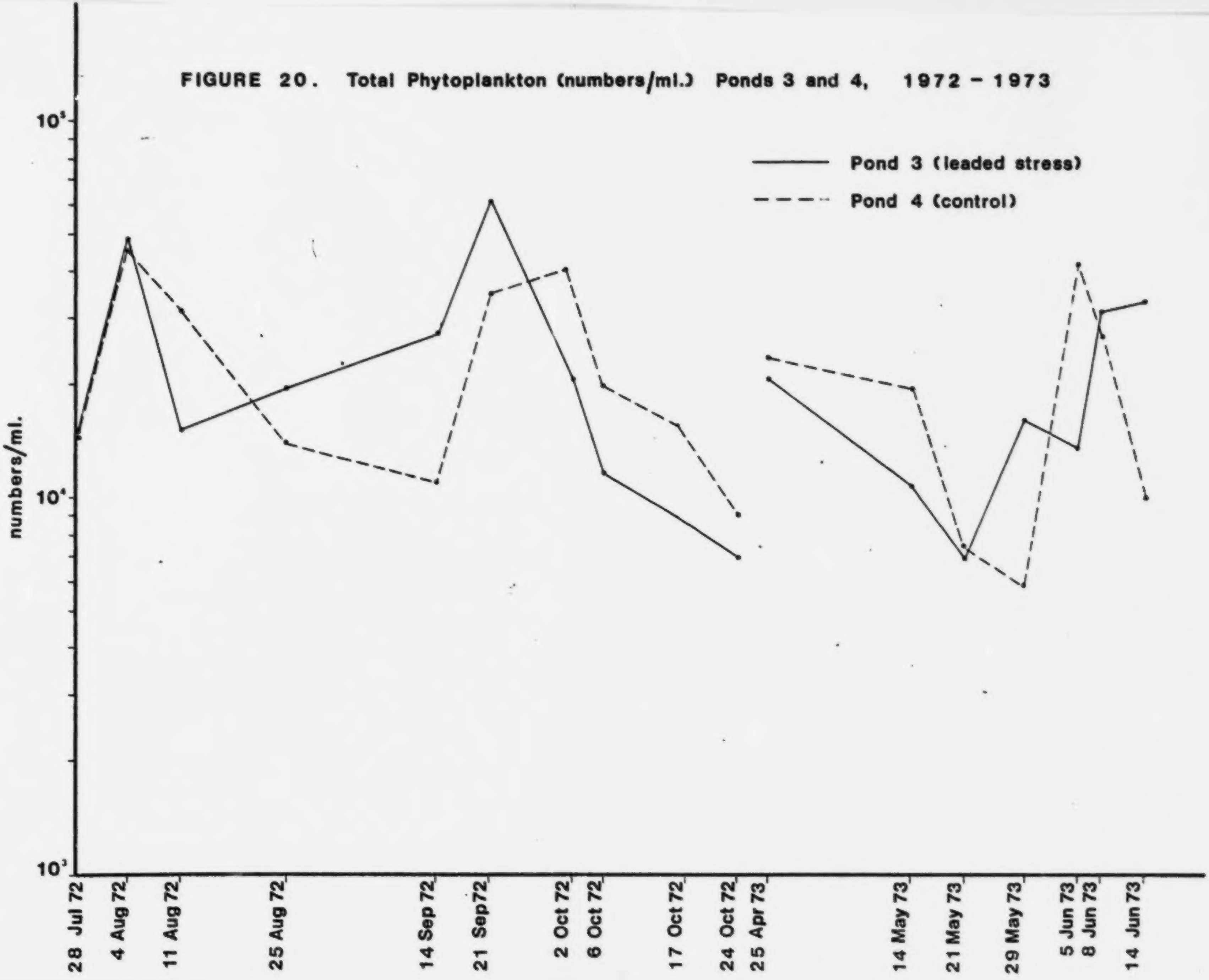


FIGURE 21 Dominant Phytoplankton Groups Ponds 1 and 2 1972-1973

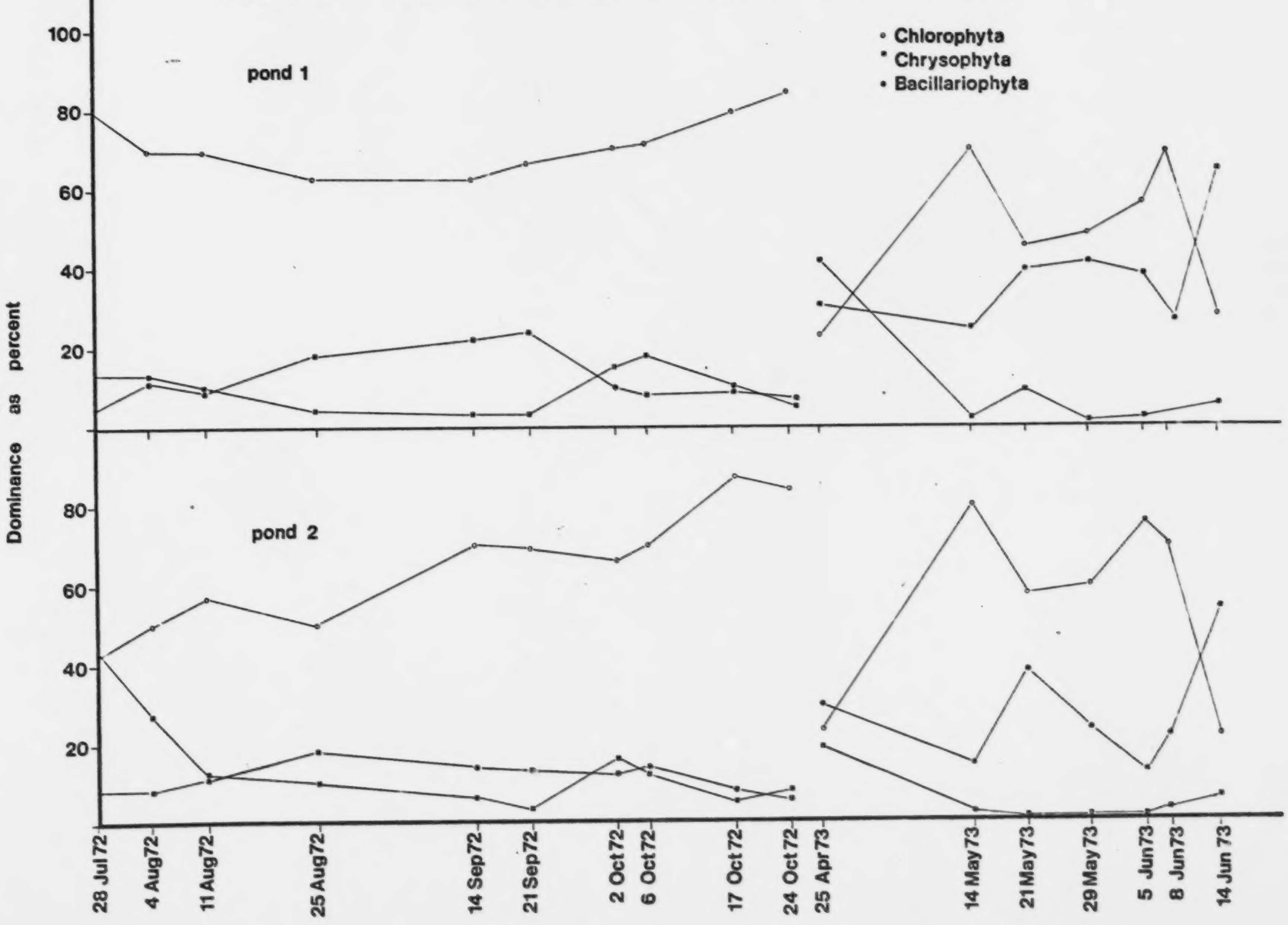
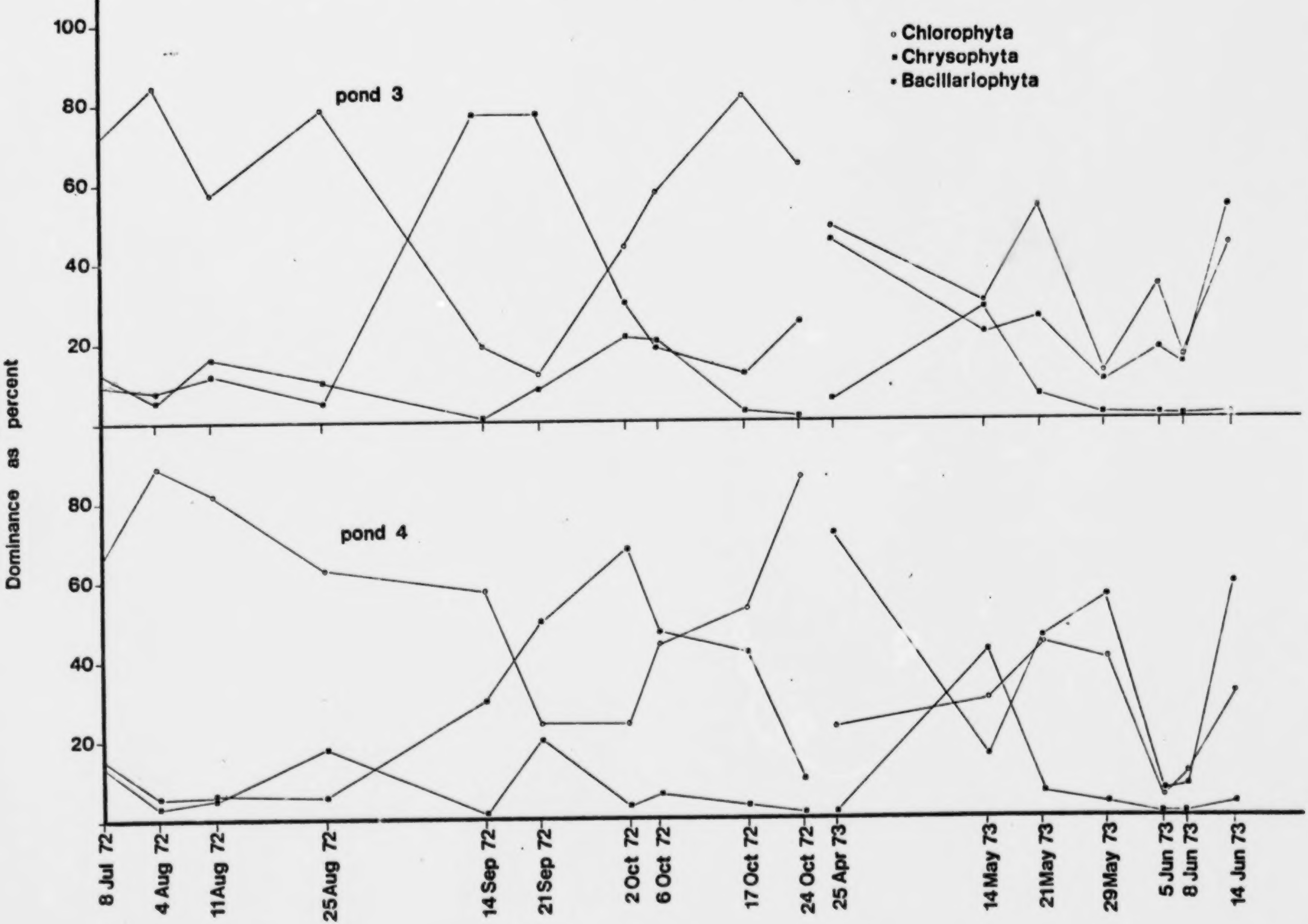


FIGURE 22 Dominant Phytoplankton Groups Ponds 3 and 4 1972 - 1973



abundant than the Chlorophyta. The blue-green algae were seldom abundant or dominant in Ponds 3 and 4 during 1972 although this group could arbitrarily be called common.

The green algae were dominant in Ponds 1 and 2 during 1973, the diatoms being abundant and becoming dominant in mid-June. During 1973, the phytoplankton populations in Ponds 3 and 4 were very unstable, having rapid shifts in species dominance (Figure 22). The diatoms and green algae were most often dominant or co-dominant with the blue-green algae being dominant in late May and early June (Appendix C-21).

Throughout the 1972-1973 collecting period, there were 137 taxa of phytoplankton identified of which only 18 taxa occurred consistently (Appendix C-22). Taxa which were most abundant represented the green algae and diatoms. The dominant species complex of green algae included:

Ankistrodesmus falcatus (Corda) Ralfs
A. spiralis (Turner) Lemm.
Chlorella vulgaris Beyerinck
Crucigenia tetrapedia (Kirch.) West and West
Golenkinia radiata (Chod.) Wille
Scenedesmus abundans (Kirch.) Chodat
S. bijuga (Turp.) Lagerheim
Selenastrum minutum (Naeg.) Collins

Another species, Acanthosphaera zachariasi Lemm., appeared in large numbers in June of 1973. The diatoms were dominated by two species, Cyclotella (c.f. comta) (Ehr.) Kuetz. and Synedra crotonensis var. prolongata Grun.

The blue-green algae were not consistent components of the phytoplankton although two blue-green blooms were observed. A late August, 1972, bloom of Oscillatoria sp. was observed in Ponds 1, 2, and 4 (Table 24). At this time numbers of individuals (filament length equal to 90μ) was between 2,000 - 15,600/ml. The second blue-green bloom occurred in Ponds 3 and 4 of the late May and early June, 1973 collections (Appendix C-21). During this period the blue-green algae comprised between 70 - 85 percent of the total phytoplankton population. The species *Oscillatoria subbrevis* Schmidle was predominant in this bloom (Appendix C-22).

Four other major groups of algae were present in the test ponds during the study period. These groups, Chrysophyta, Euglenophyta, and Cryptophyta, were often common but never dominant. The Pyrrhophyta was represented mostly by *Glenodinium quadridens* (Stein) Schiller and the Crytophyta by *Rhodomonas lacustris* Pascher and Ruttner. Common to the Chrysophyta were *Dinobryon bavaricum* Imhof, *D. sertularia* Ehr., and *Chrysococcus rufescens* Klebs. The Euglenophyta was often represented by *Euglena* sp. (*E. elastica* Prescott and *E. oxyuris* Schmarda) and *Trachelomonas volvocina* Ehr.

Species richness ($S/\sqrt{N}$) (Table 23 and Figure 23) shows the test ponds to be similar. Not only is richness similar but the ponds responded together as pond-pairs (Ponds 1-2 and Ponds 3-4). Richness during 1973 was less than 1972 yet pond-pairs responded together. Calculated mean and standard deviation values given in Table 25 further indicate the close similarity of adjacent ponds as well as between all four test ponds. This table likewise indicates the species richness to be lower during 1973 than during 1972 in all ponds.

A second species richness index, ($S-1/\ln N$), revealed similar patterns as discussed previously (Table 23 and Figure 24).

TABLE 24

INCIDENTAL DATA OF BLUE-GREEN ALGAE BLOOM - 1972
Numbers are *Oscillatoria* sp. (number of 90μ Filaments/ml)

Date	Pond 1	Pond 2	Pond 3	Pond 4
25 Aug	1,575	890	25	0
28 Aug	4,206	6,013	160	2,369
31 Aug	6,719	8,338	345	15,672

TABLE 25

MEAN AND STANDARD DEVIATION OF SPECIES RICHNESS ($S/\sqrt{N}$)

1972	Pond 1	Pond 2	Pond 3	Pond 4
Mean	0.422	0.430	0.313	0.301
Standard Deviation	0.078	0.096	0.103	0.082
1973				
Mean	0.210	0.214	0.160	0.201
Standard Deviation	0.043	0.038	0.038	0.080

FIGURE 23. Phytoplankton Richness 1972-1973 (S/√N)

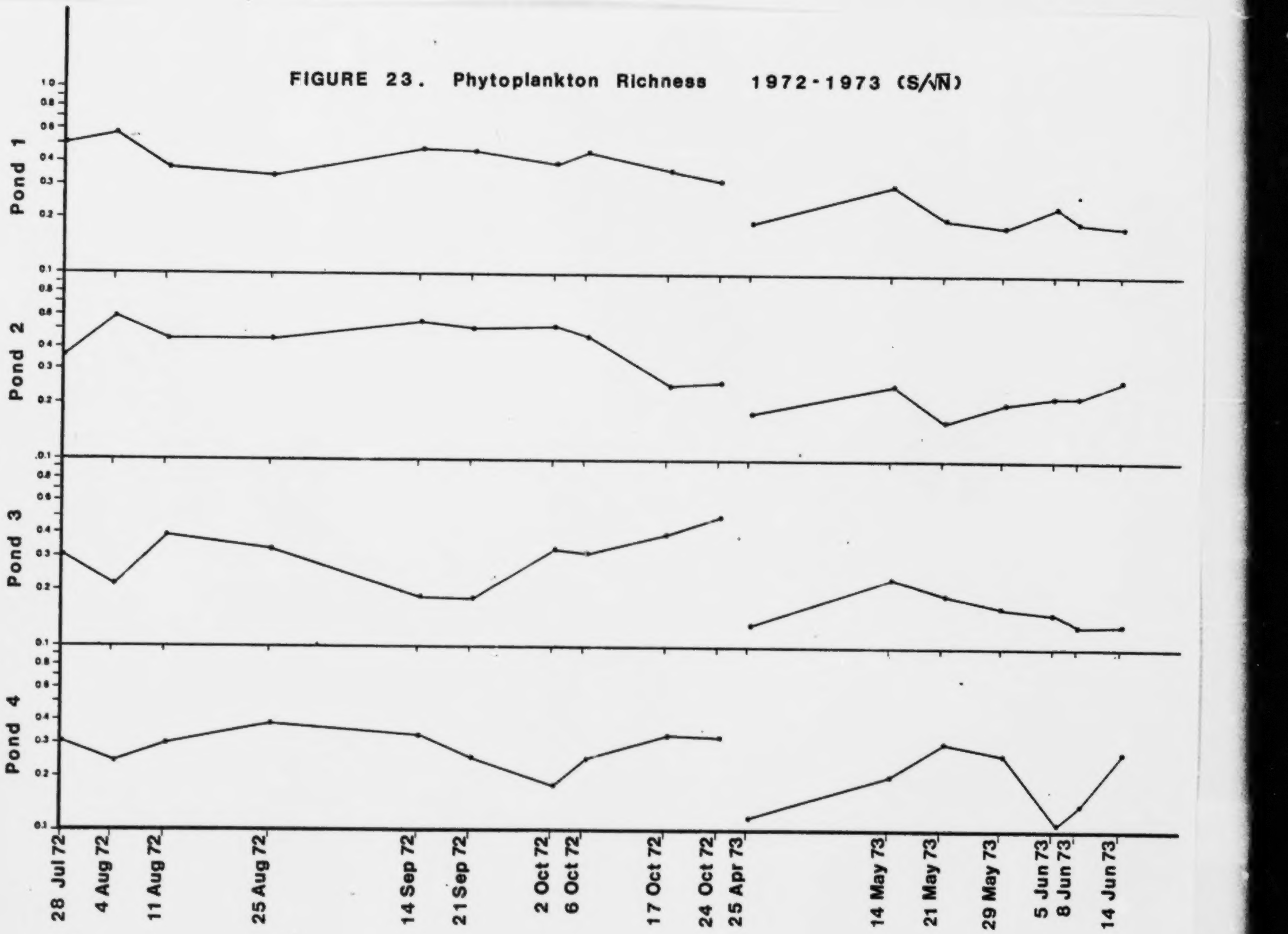
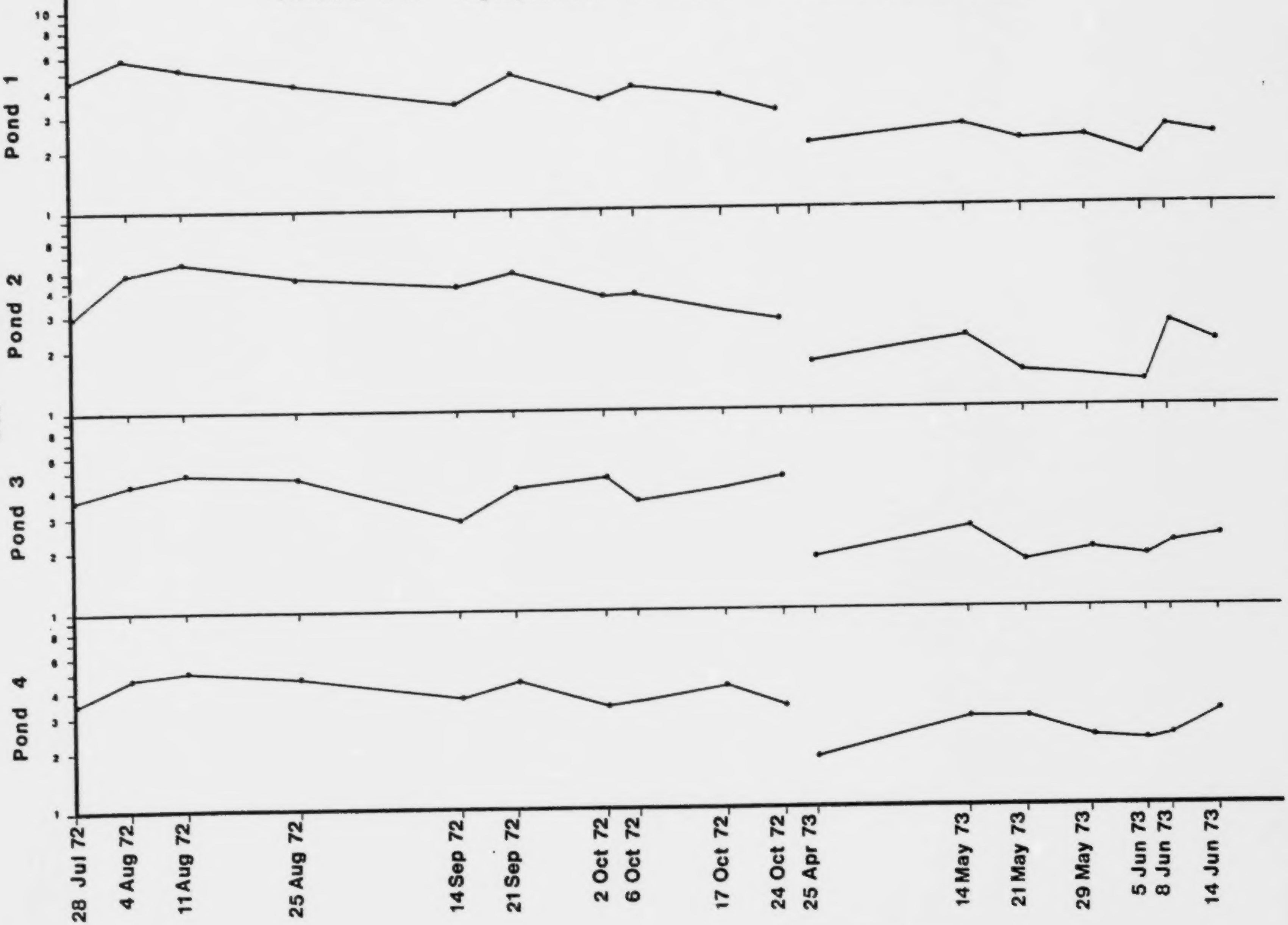


FIGURE 24. Phytoplankton Richness 1972-1973 (s-1/1nN)



Different from the previous index the calculated trends of the four test ponds were very similar. Again, the richness was lower in 1973 than in 1972. Calculated mean and standard deviation values (Table 26) indicate the close relationship between all test ponds as well as an annual difference.

The Sorenson's similarity coefficeint further characterizes the four test ponds as having similar phytoplankton populations. Comparisons were drawn between adjacent stress and control ponds, Ponds 1-2 and Ponds 3-4; between stress ponds, Ponds 1 and 3 and between control ponds, Ponds 2 and 4. With a lower limit of 0.500 to denote a lack of similarity, (84) all combinations of populations tested showed a high level of similarity with few exceptions (Tables 27 and 28). Figures 25 and 26 show that similar trends occurred between pond-pairs. Population similarity was more analogous when adjacent ponds were compared as opposed to distal ponds. That is, the similarity trends were nearly parallel when comparing Ponds 1-2 to Ponds 3-4. The trends of Ponds 1-3 compared to Ponds 2-4 were more different.

The phytoplankton populations in the test ponds vary according to natural, cyclic phenomena following patterns of seasonal succession common to most freshwater lakes. During 1971, the dominant species were common to all test ponds although peak populations did not occur simultaneously in all test ponds. This held true for the phytoplankton populations in 1972 and 1973. Phytoplankton is regulated by many factors which include light, temperature, chemical factors such as pH, salinity, and nutrients (carbon, nitrogen, phosphorous), physical factors such as current and turbidity, and biological factors such as metabolic

TABLE 26

MEAN AND STANDARD DEVIATION OF RICHNESS (S-1/lnN)

1972	Pond 1	Pond 2	Pond 3	Pond 4
Mean	4.233	4.005	4.118	4.013
Standard Deviation	0.852	0.922	0.623	0.637
1973				
Mean	2.270	2.177	2.006	2.416
Standard Deviation	0.304	0.472	0.275	0.464

TABLE 27

PHYTOPLANKTON SIMILARITY COEFFICIENTS 1972-1973
Comparing Control With Stress Ponds

Date	Numbers of Species			Sorenson's	Jaccard's
	Pond 1 (a)	Pond 2 (b)	Common (c)	$\frac{2c}{a+b}$	$\frac{c}{a+b-c}$
28 Jul 72	41	27	18	0.529	0.360
4 Aug 72	54	43	37	0.763	0.617
11 Aug 72	54	53	36	0.673	0.507
25 Aug 72	42	43	33	0.776	0.635
14 Sep 72	29	35	25	0.781	0.641
21 Sep 72	44	37	34	0.840	0.723
2 Oct 72	32	31	22	0.698	0.537
6 Oct 72	37	33	22	0.629	0.458
17 Oct 72	35	31	24	0.727	0.571
24 Oct 72	29	27	19	0.679	0.514
25 Apr 73	21	16	14	0.757	0.609
14 May 73	23	21	12	0.545	0.375
21 May 73	21	20	11	0.537	0.367
29 May 73	22	18	12	0.600	0.429
5 Jun 73	16	17	13	0.788	0.650
8 Jun 73	25	26	18	0.706	0.545
14 Jun 73	30	31	23	0.754	0.605

Date	Pond 3 (a)	Pond 4 (b)	Common (c)	Sorenson's	Jaccard's
28 Jul 72	35	34	26	0.754	0.605
4 Aug 72	47	52	39	0.788	0.650
11 Aug 72	46	52	37	0.755	0.607
25 Aug 72	47	45	35	0.761	0.614
14 Sep 72	30	35	24	0.738	0.585
21 Sep 72	32	47	38	0.962	0.927
2 Oct 72	46	36	30	0.732	0.577
6 Oct 72	34	36	25	0.714	0.556
17 Oct 72	38	41	29	0.734	0.580
24 Oct 72	42	31	27	0.740	0.587
25 Apr 73	19	19	14	0.737	0.583
14 May 73	24	29	20	0.755	0.606
21 May 73	16	25	11	0.537	0.367
29 May 73	20	20	12	0.600	0.429
5 Jun 73	18	23	15	0.732	0.577
8 Jun 73	23	24	16	0.681	0.516
14 Jun 73	26	31	17	0.596	0.425

TABLE 28

PHYTOPLANKTON SIMILARITY COEFFICIENT
COMPARING STRESS PONDS - #1 and #3

Date	(a) Pond 1	(b) Pond 3	(c) Ponds 1 & 3	Sorenson's Value
28 Jul 72	41	35	23	0.605
4 Aug 72	54	47	38	0.752
11 Aug 72	54	46	32	0.640
25 Aug 72	42	47	29	0.652
14 Sep 72	29	30	19	0.644
21 Sep 72	44	32	32	0.842
2 Oct 72	32	46	27	0.692
6 Oct 72	37	34	25	0.704
17 Oct 72	35	38	27	0.740
24 Oct 72	29	42	21	0.592
25 Apr 73	21	19	13	0.650
14 May 73	23	24	13	0.553
21 May 73	21	16	10	0.541
29 May 73	22	20	12	0.571
5 Jun 73	16	18	10	0.588
8 Jun 73	25	23	16	0.667
14 Jun 73	30	26	17	0.607

SIMILARITY COEFFICIENT COMPARING CONTROL PONDS - #2 with #4

Date	(a) Pond 2	(b) Pond 4	(c) Ponds 2 & 4	Sorenson's Value
28 Jul 72	27	34	18	0.590
4 Aug 72	43	52	33	0.695
11 Aug 72	53	52	31	0.590
25 Aug 72	43	45	35	0.795
14 Sep 72	35	35	19	0.543
21 Sep 72	37	47	29	0.690
2 Oct 72	31	36	20	0.597
6 Oct 72	33	36	22	0.638
17 Oct 72	31	41	24	0.667
24 Oct 72	27	31	20	0.690
25 Apr 73	16	19	13	0.743
14 May 73	21	29	14	0.560
21 May 73	20	25	13	0.578
29 May 73	18	20	10	0.526
5 Jun 73	17	23	14	0.700
8 Jun 73	26	24	17	0.680
14 Jun 73	31	31	16	0.516

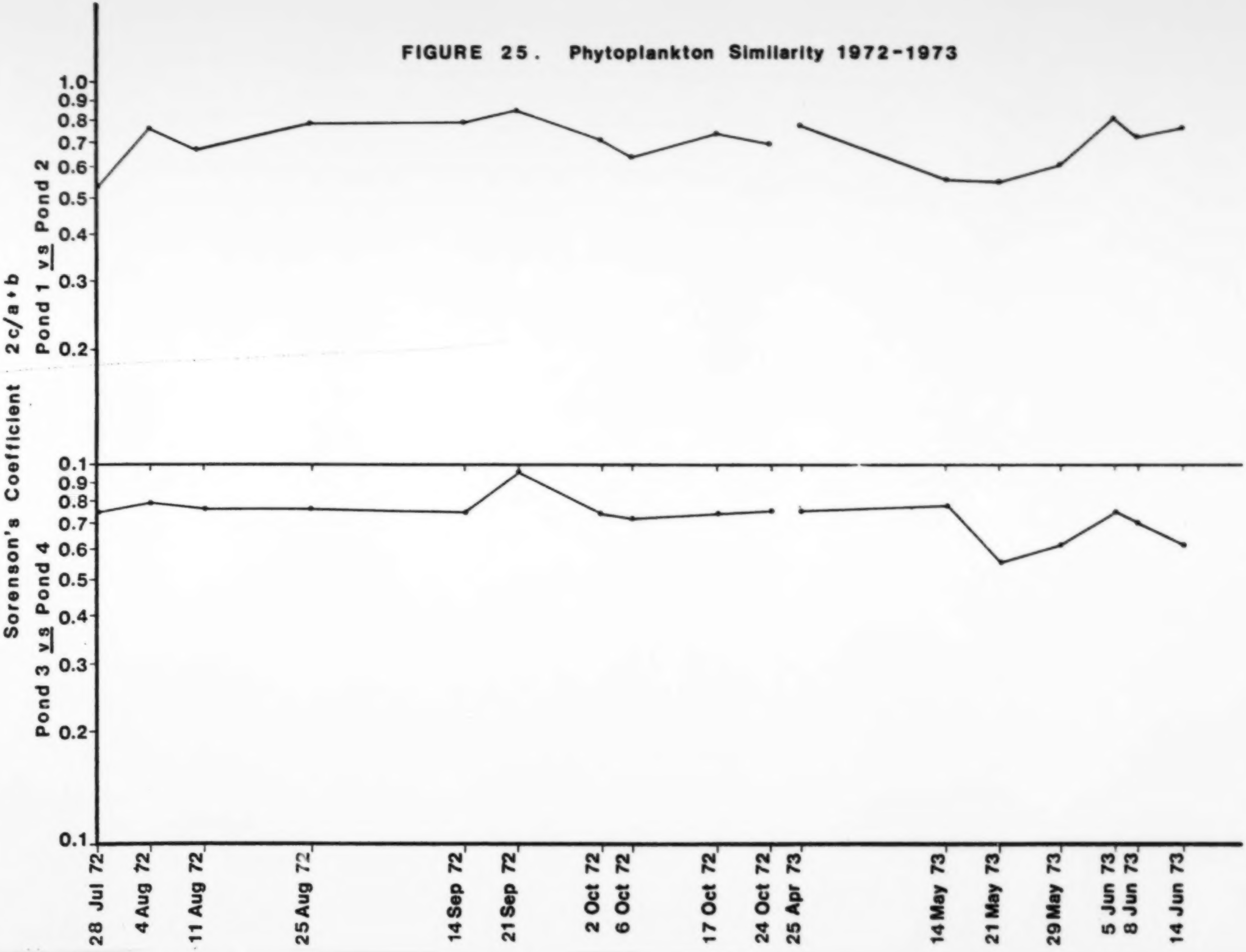
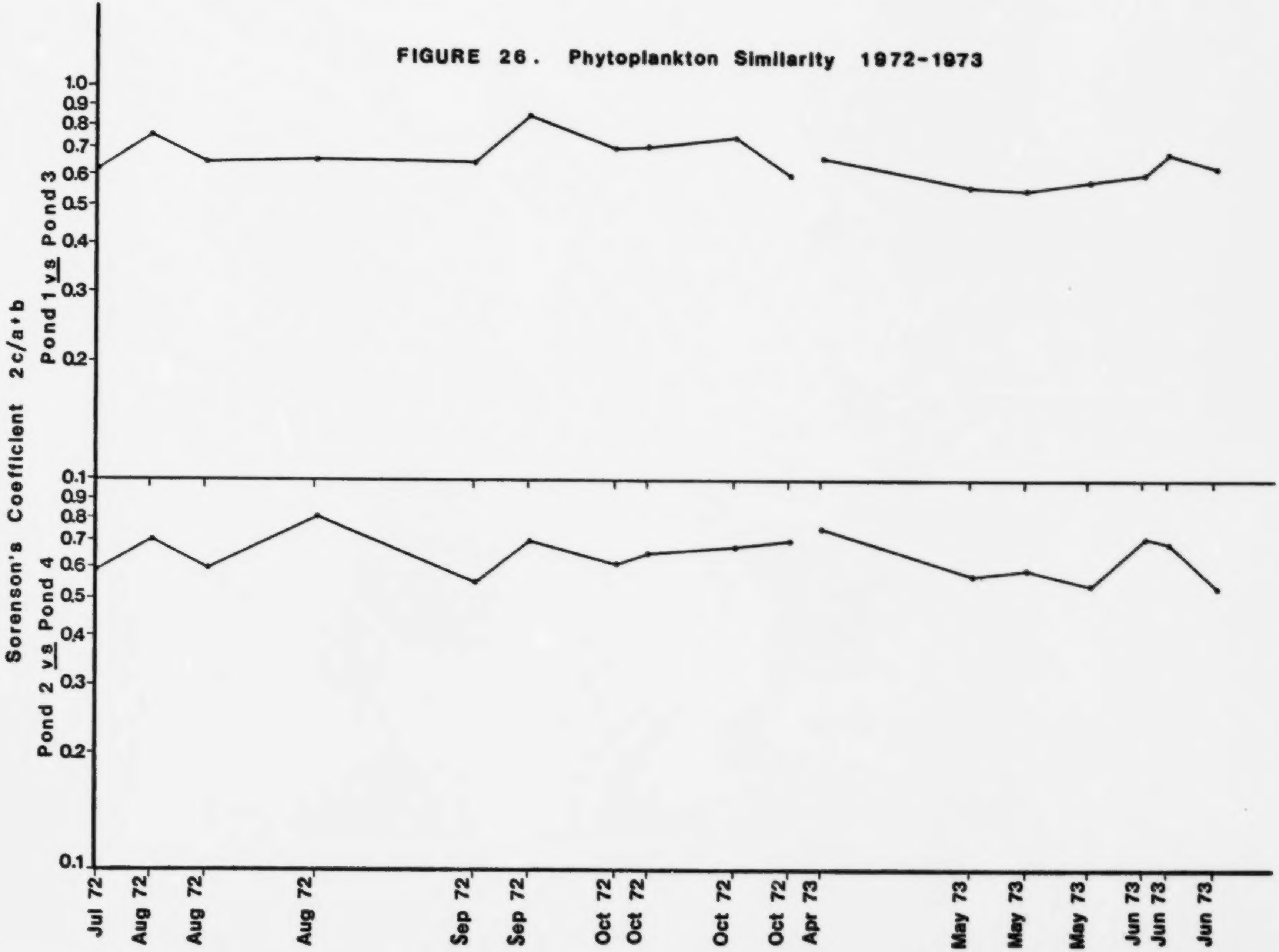


FIGURE 25. Phytoplankton Similarity 1972-1973

FIGURE 26. Phytoplankton Similarity 1972-1973



by-products, toxins and competition, Reid(83), Welch (50), and Hutchinson (95). In general it can be stated that temperature and nutrients regulate seasonal succession. The diatoms are considered as cold water, winter dominants; the green algae occur during the summer; and blue-green algae are more dominant under the low nutrient, warmer waters of late summer, Cairns (96), Reid (83), and Welch(50). The occurrence of dominant groups in the test ponds was very similar to the general seasonal trends regulated by temperature and nutrients.

Biomass variations (1971) are reflected mostly in the occurrence and abundance of tychoplanktonic species. Greatest biomass of tychoplankters occurred in the control ponds (Ponds 2 and 4). Since the test ponds were of common origin, i.e., Ponds 1 and 2 were the result of dividing one pond and Ponds 3 and 4 were the result of dividing a second pond, one would assume few initial differences in the species associations of pond-pairs. In general this did occur. The species comprising this category of phytoplankton are the diatoms, both those forms commonly unattached or attached to substrate surfaces, and those forms which are sometimes dominant in the open waters of lakes. The abundance of these forms in the plankton of the control ponds would represent independent species pulses in different bodies of water, but one would expect similar pulses, with certain lag periods, in the stress ponds. One would also expect the turbulence created by the test engines in the stress ponds to resuspend these forms (tychoplankters = diatoms) in the water column. This would theoretically increase the recorded biomass of phytoplankton in the stress ponds but this was not observed. Other dominant species, euplankters, did exhibit asynchronous pulses in the test ponds throughout the fall of 1971. It cannot be said that outboard engine stressing was responsible for the lower biomass values of tychoplankton in the stress ponds especially when the data of 1972 and 1973 are considered. The dominant species complex of the tychoplankton in 1971 was *Achnanthes* spp., *Gomphonema* spp., and *Synedra* spp., these same taxa were dominants in both the plankton and periphyton of all test ponds during 1972 and 1973.

Phytoplankton species dominance and occurrence in the test ponds during 1972 and 1973 reflect seasonal trends similar to those of other north-temperate lakes. Furthermore these trends are regulated by nutrient levels and temperature as annual population dynamics correlate with increases and decreases with nitrogen, phosphorus, and temperature (c.f. Chemistry Section this report). Peak populations in Ponds 1 and 2 (numbers/ml) are closely associated with high levels of nitrogen and phosphorus. For example, the population of 20,992 plankters/ml in Pond 1 on August 11, 1972 was preceded by 0.14 ppm total phosphorus and 0.32 ppm nitrate nitrogen on August 7, 1972. Likewise, the 15,166 individuals/ml in Pond 2 was preceded by 0.13 ppm total phosphorus and 0.30 ppm nitrate nitrogen on these same dates. Although the trend is one of decreasing numbers of phytoplankton from August 11 to September 14, 1972 this pulse is associated with high levels of nitrogen and phosphorus. Since phytoplankton was observed on a seven to 14 day basis during some periods, the exact population maxima are not known. The same holds true for nutrient analysis. Similar associations were observed in Ponds 3 and 4. For example, there were 62,641 plankters/ml in Pond 3 on September 21, 1972 which was preceded by 0.033 ppm total phosphorus (September 11) and 0.31 ppm nitrate nitrogen (September 18). The population of 34,863 individuals/ml in Pond 4 was preceded by 0.30 ppm total phosphorus (September 11) and 0.33 ppm nitrate nitrogen (September 18). Increases in population numbers were associated with high levels of phosphorus on August 7, 1972, September 11, 1972, October 23, 1973, and June 18, 1973.

Dominant groups of species, e.g., Chlorophyta, Chrysophyta, and Bacillariophyta, did not associate as closely as expected to temperature in the test ponds. The green algae were dominant in Ponds 1 and 2 when the temperature ranged from 24°C on July 31, 1972 to 7°C on October 24, 1972. In Ponds 3 and 4 the diatoms dominated for a short period when the temperature ranged from 21°C August 15, 1972 to 17°C October 2, 1972. The dominance of these groups does not correlate well with temperature ranges found in the literature.

Shifts in species richness ($S/\sqrt{N}$) were quite similar in pond-pairs; any observed differences were not significant statistically. The results of a two-tailed paired t-test (95% confidence level) are given in Table 30. Comparison of mean values of Pond 1 vs. 2 and Pond 3 vs. 4 from 1972 and 1973 are nearly identical and calculated F values never approached the critical F values. These data, along with the similarity coefficients, indicate that the initial supposition of similar populations in pond-pairs was valid. It is further shown that there were no significant variations in species richness caused by outboard engine stressing.

Shifts in species richness ($S-1/\ln N$) were also quite similar in pond-pairs. Comparison of mean richness values (Table 30) indicated near identical values with no significant difference being observed. The two-tailed paired t-test (95% confidence level) showed the difference in richness

Table 29. COMPARISONS OF ABUNDANCE OF THE 26 MAJOR PHYTOPLANKTON SPECIES

Species	pond 1 vs. pond 2			Pond 3 vs pond 4			
	equal	1 >2	1 <2	equal	3>4	3<4	absent
Ankistrodesmus spiralis	X			X			
Scenedesmus dimorphus	X			X			
Peridinium inconpicuum	X			X			
Centritractus belonophorus	X			X			
Synedra tenera	X			X			
Trachelomonas volvocina	X			X			
Σ *Euglena* spp.	X			X			
Lepocinclis glabra	X			X			
Cyclotella stelligera var. *tenuis*	X				X		
Kephyrion ovale	X				X		
Nitzschia acicularis	X					X	
Phacus contortus	X						X
Dinobryon sociale		X		X			
Ceratium hirundinella			X	X			
Peridinium conningtonii			X	X			
Phacus orbicularis			X	X			
Trachelomonas hispida			X	X			
Crucigenia tetrapedia			X	X			
Dictyosphaerium pulchellum			X	X			
Scenedesmus bijuga		X			X		
Synedra delicatissima		X			X		
Anabaena sp.		X					X
Glenodinium sp.			X			X	
Closterium acutum			X			X	
Strombomonas maxima			X				X
Strombomonas sp. 2							
	12	4	10	15	3	4	4

(29 rare spp not included)

Table 30. PHYTOPLANKTON STATISTICS
Paired t-Test - 95%
Confidence Level

Parameter	Year	Test Ponds	df	$\overline{Y}$	$S_{\overline{Y}}$	$\overline{X}$	$S_{\overline{X}}$	F value	t_s	t_s^2	sig.
Phytoplankton productivity MgC/m^3/hr	1971	1 vs. 2	5	34.45	19.53	68.24	55.62	10.0	1.99	3.97	
	1972	1 vs. 2	11	39.80	18.69	51.52	29.67	6.72	3.09	9.54	*
	1973	1 vs. 2	5	11.44	8.68	11.31	9.49	10.0	-0.05	<0.01	
	1971	3 vs. 4	5	38.62	28.86	40.20	7.86	10.0	0.14	0.02	
	1972	3 vs. 4	11	60.92	25.49	72.85	31.57	6.72	2.39	5.71	
	1973	3 vs. 4	5	15.21	15.61	12.00	16.01	10.0	-0.96	0.92	
Chlorophyll a mg/m^3	1973	1 vs. 2	13	16.45	10.47	15.82	7.52	6.41	-0.37	0.14	
	1973	3 vs. 4	13	20.58	6.90	32.40	14.94	6.41	2.86	8.18	*
Productivity Index, $\frac{\text{MgC/m}^3\text{/hr}}{\text{mgChl } a\text{/m}^3}$	1973	1 vs. 2	4	1.05	0.76	1.06	0.89	12.2	0.02	<0.01	
	1973	3 vs. 4	4	1.07	0.88	0.54	0.86	12.2	-1.79	3.22	
Diversity	1972	1 vs. 2	9	0.42	0.08	0.44	0.12	7.21	0.52	0.27	
	1973	1 vs. 2	6	0.21	0.04	0.21	0.04	8.81	0.24	0.06	
	1972	3 vs. 4	9	0.31	0.10	0.29	0.06	7.21	-0.76	0.58	
	1973	3 vs. 4	6	0.16	0.04	0.20	0.08	8.81	1.43	2.04	
Richness	1972	1 vs. 2	9	4.23	0.85	4.00	0.92	7.21	-1.07	1.14	
	1973	1 vs. 2	6	2.27	0.30	2.18	0.47	8.81	-0.87	0.76	
	1972	3 vs. 4	9	4.12	0.64	4.01	0.64	7.21	-0.47	0.22	
	1973	3 vs. 4	6	2.01	0.28	2.42	0.46	8.81	2.66	7.09	

1973 ENGINE RUN STATISTICS - CHLOROPHYLL a mg/m^3 Paired t-Test - 95% Confidence Level

	df	$\overline{Y}$	$S_{\overline{Y}}$	$\overline{X}$	$S_{\overline{X}}$	F value	t_s	t_s^2	sig.
Pond 1									
From dock before versus during	7	17.82	7.46	25.77	8.72	8.07	4.20	17.66	*
Before versus cooling	7	17.82	7.46	24.75	11.48	8.07	2.01	4.02	
Submerged before versus during	7	26.22	10.07	24.46	7.02	8.07	-0.91	0.83	
Pond 3									
From dock before versus during	7	23.00	11.06	23.53	8.03	8.07	0.27	0.08	
Before versus cooling	7	23.00	11.06	26.34	11.52	8.07	3.19	10.16	
Submerged before versus during	7	28.59	5.98	26.55	9.24	8.07	-0.77	0.60	

(S-1/lnN) between Ponds 3 and 4, 1973, to approach significance. These differences are likely the result of a bloom of blue-green algae and changes in the species of green algae which occurred on opposing dates. Since both test ponds (Ponds 3 and 4) exhibited these species pulse-phenomena, i.e., blooms, and although the pulses occurred at different times, these variations must be called natural and not the result of outboard engine stressing.

Four comparisons of phytoplankton population similarity between test ponds indicated a high similarity of species associations between all ponds. Control and stress ponds within the same pond-pair were very similar, Pond 1 (non-leaded stress) being similar to its control (Pond 2) and Pond 3 (leaded stress) being similar to its control (Pond 4). Further comparisons between pond-pairs produced the same results, where the stress ponds (Pond 1 and Pond 3) were similar as were the control ponds (Pond 2 and Pond 4). The extent to which these comparisons show population similarity indicates that the presence of outboard engine stressing did not affect the composition of species associations in the test ponds.

Analysis of the phytoplankton populations showed no significant stress effects by outboard engines on the abundance and occurrence of phytoplankton species associations. The population similarity coefficients and species richness indices reflect similar populations in all test ponds from the onset of this study. These biomathematical values validate an early assumption that the populations in pond-pairs (Ponds 1-2 and Ponds 3-4) would be nearly identical as they originated from the same waters. The data has shown that similarity of species complexes did not change significantly over the three year duration of this study and that the respective phytoplankton populations responded to natural factors such as nutrients and not to outboard engine stressing.

Short Term Population Dynamics - Comparisons were made between two independent phytoplankton samples collected daily, August 12 - August 16, 1973, from each of the four test ponds. Counts for 56 species plus an uncertain number of *Euglena* species were obtained from each subsample. Of these, 26 species were considered sufficiently abundant to be analyzed statistically, while the others were either rare or difficult to reliably identify and enumerate. The data of the 26 species to be analyzed were arranged according to a randomized block design with replication, with the four ponds as treatments and the five sampling days as blocks.

Table 29 summarizes the results of the pair-wise comparisons of population size in Ponds 1 and 2 (non-leaded stress and its control) and Ponds 3 and 4 (leaded stress and its control). For most of the species, population size in the stress and control sections were not significantly different. Population size of ten species was higher in Pond 2 (control) than in Pond 1 (non-leaded stress), with the exception of *Crucigenia tetrapedia* and *Dictyosphaerium pulchellum* which were relatively rare organisms. Two small species, *Scendesmus bijuga* and *Anabaena* sp., were more abundant in Pond 1 than in Pond 2. Four species, one of which was *Nitzschia acicularis*, were more abundant in Pond 4 (control) than in Pond 3 (leaded stress). Three species, all of which were small and numerous, were more abundant in Pond 3 than in Pond 4.

The arrangement of data according to a randomized block design enabled statistical analysis by the nonparametric Friedman Procedure for two way analysis of variance by ranks(97). A nonparametric method was considered preferable to methods based on normal statistics because of the expected patchy distribution of phytoplankton in the test ponds.

The Friedman test identified the species for which there were significant differences (0.95 levels) in population size between ponds during the five day sampling period. To determine where the differences occurred, Wilcoxon's two sample test (98), was employed to test all six possible pairs of ponds. To use this test all data of the five days from each pond were combined, yielding ten observations per species per pond. Of particular interest were differences between the control and treatment sides of each original divided pond.

For most of the species, population size in the stress and control sections were not significantly different (0.95 level). Population size was significantly higher for ten species in Pond 2 (control) than in Pond 1 (non-leaded stress). The quantitative comparisons of phytoplankton population sizes over the five day period, August 12 through August 16, 1972 provided no striking evidence for either a negative or a positive effect by either stress condition.

Primary Productivity - Carbon productivity was measured throughout the duration of the northern lake study. During this three year period measurements were made on 24 dates: 1971 - six dates (August 14 - October 19), 1972 - 12 dates (July 28 - October 17), and 1973 - 6 dates (May 14 - August 20). Mean ^{14}carbon productivity values for 1971-1973 are presented in Table 31. From this table it is seen that mean carbon production was most often greater in the control ponds (Ponds 2 and 4) than in the stress ponds (Ponds 1 and 3). For the entire three year collecting period the stress ponds had lower productivity values than the control ponds on 77 percent of the collection dates (Table 32). Pond 1 (non-leaded stress) was less productive than its adjacent control (Pond 2) on 79 percent of the collection dates, Pond 3 (leaded stress) was less productive than its control (Pond 4) on 75 percent of the collection dates. It was further found that Pond 1 (non-leaded stress) was less productive than Pond 3 (leaded stress) on 75 percent of the collection dates. Likewise, Pond 2 had lower productivity than Pond 4 on 71 percent of the collection dates. ^{14}Carbon productivity was compared between pond-pairs for the three collecting periods of this study. The data has shown Pond 1 (non-leaded stress) to be less productive than Pond 2 (control) during 1971, 1972, and 1973. This difference was statistically significant during 1972 (two-tailed paired t-test, 95% confidence), where mean production in Pond 1 was 39.80 mgC/m^3/hr. as compared to Pond 2 which was 51.52 mgC/m^3/hr. The standard deviations were 18.69 and 29.67 respectively (Table 30). The leaded stress pond (Pond 3) likewise had

TABLE 31

Mean Phytoplankton Productivity*

DATE	Pond 1	Pond 2	Pond 3	Pond 4
1971				
14 Aug	37.18	26.20	81.90	46.93
27 Aug	63.30	174.43	65.20	37.98
19 Sep	29.15	71.20	31.20	45.80
28 Sep	17.85	41.23	17.20	47.98
12 Oct	10.68	27.20	7.40	29.43
19 Oct	48.55	69.20	28.85	33.05
1972				
28 Jul	29.53	42.13	46.85	52.33
4 Aug	30.78	28.48	70.79	60.05
11 Aug	34.90	45.33	55.33	55.43
18 Aug	41.25	70.33	84.03	137.15
25 Aug	71.53	107.65	90.78	101.33
1 Sep	59.23	85.55	59.75	86.40
8 Sep	45.55	55.10	51.55	76.75
14 Sep	63.40	73.00	97.80	99.88
22 Sep	47.30	61.55	87.68	88.85
2 Oct	18.93	19.53	26.80	49.80
6 Oct	27.13	20.58	37.98	44.45
17 Oct	8.13	9.03	21.70	21.78
1973				
14 May	0.17	0.55	0.20	0.26
21 May	7.95	6.13	4.95	9.08
14 Jun	21.23	23.20	41.28	43.65
10 Jul	3.90	12.98	6.30	1.53
23 Jul	19.48	21.45	12.35	9.88
20 Aug	15.90	3.53	26.18	7.63

* (mg C fixed/m^3/hr.)

Table 32. PRODUCTIVITY OF STRESS COMPARED TO CONTROL PONDS

	Pond 1 < Pond 2	Pond 3 < Pond 4
1971	5 of 6 collections (0.833)	4 of 6 collections (0.666)
1972	10 of 12 collections (0.833)	11 of 12 collections (0.916)
1973	4 of 6 collections (0.666)	3 of 6 collections (0.500)
Total	19 of 24 collections (0.791)	18 of 24 collections (0.750)

Combined: Stress < Control 74 of 96 collections (.0771) less production than its control (Pond 4) during the three collecting periods. A two-tailed paired t-test (95% confidence) showed these differences not to be significant.

The observed differences in productivity between stress and control test ponds do not appear to be the result of natural population dynamics and ecological factors. Previous discussion has shown the pond-pairs to have near identical phytoplankton populations in terms of species composition, total numbers, species richness, and similarity. Water chemistry analysis also shows very similar trends in nutrient levels and temperature in all four test ponds. From these data one would expect the primary productivity in the test ponds, especially pond-pairs, to be very similar. Productivity differences were not statistically significant except for Ponds 1 and 2 during 1972. This significance is not the result of different phytoplankton species associations according to the species richness and similarity coefficient data. Species richness was alike in Ponds 1 and 2 and population similarity values were seldom below 0.65 (mean = 0.71) during 1972. Similarity values less than 0.50 are considered as being significantly different. It was also observed that the same groups of algae dominated the phytoplankton population during the period in question. From these data it is felt that the presence of outboard engine stressing with non-leaded fuel did exhibit an effect on phytoplankton productivity (mg C fixed/m^3/hr.) during 1972.

Chlorophyll - Chlorophyll a measurements were taken from nine samples collected during May 14 - August 20, 1973.

The data presented in Table 33 and Figure 27 show that chlorophyll a (mg/m^3) follows similar trends in the test ponds. Values in Ponds 1 and 2 were very similar, closely paralleling each other throughout the summer. Chlorophyll a in Ponds 3 and 4 followed close trends up until June 14, 1973 when Pond 4 values increased and Pond 3 values decreased. In Ponds 3 and 4 chlorophyll a did not closely parallel each other after June 14, 1973.

The minor variations in chlorophyll a (mg/m^3) between test Ponds 1 and 2 (non-leaded stress and its adjacent control) were not statistically significant. The results of a two-tailed paired t-test, 95% confidence level, are presented in Table 30. This table indicates a close similarity in chlorophyll a values between Ponds 1 and 2 with mean chlorophyll a values of 16.45 mg/m^3 and 15.82 mg/m^3 respectively. There was a statistically significant difference between chlorophyll a levels in Ponds 3 and 4. Mean chlorophyll a (mg/m^3) in Pond 3 was 20.58 with a standard deviation of 6.90 as compared to Pond 4, 32.40 mg/m^3 with a standard deviation of 14.94.

It is difficult to explain the significance of the variation in chlorophyll a values from the test ponds, especially Ponds 3 and 4. An attempt to correlate chlorophyll a with numbers of individuals/ml was unsuccessful. Chlorophyll was measured on nine dates (May 14 through August 20, 1973) during which time only five enumerations of phytoplankton species occurred, May 14 - June 14, 1973. Previous discussion indicated similarity between the phytoplankton of pond-pairs when species richness, and population similarity coefficients were considered. It was noted that differences in richness

TABLE 33

Phytoplankton Chlorophyll a and Productivity Index From Routine Collections

DATE	Chlorophyll a (mg/m^3)				Productivity Index $\left(\frac{\text{mg C/m}^3\text{/hr.}}{\text{mg Chl. a/m}^3}\right)$			
	Pond 1	Pond 2	Pond 3	Pond 4	Pond 1	Pond 2	Pond 3	Pond 4
14 May 73	41.180	29.739	34.828	40.324				
	36.250	29.304	33.088	50.039	0.004	0.019	0.006	0.006
29 May 73	16.240	23.518	23.794	24.098				
5 Jun 73	16.806	11.586	22.517	34.276				
	8.279	11.310	22.386	22.386				
8 Jun 73	15.543	16.675	20.300	12.325				
14 Jun 73	11.338	14.018	21.862	22.021				
	21.820	9.280	16.352	20.861	1.280	1.992	2.160	2.036
10 Jul 73	5.800	6.960	9.280	23.008	0.672	1.864	0.679	0.066
23 Jul 73	15.321	17.535	18.202	23.092				
	15.321	20.600	16.122	21.932	1.271	1.125	0.720	0.439
7 Aug 73	10.796	7.734	19.998	44.291				
20 Aug 73	8.332	9.355	14.672	61.073				
	7.288	13.899	14.670	53.919	2.036	0.303	1.784	0.133

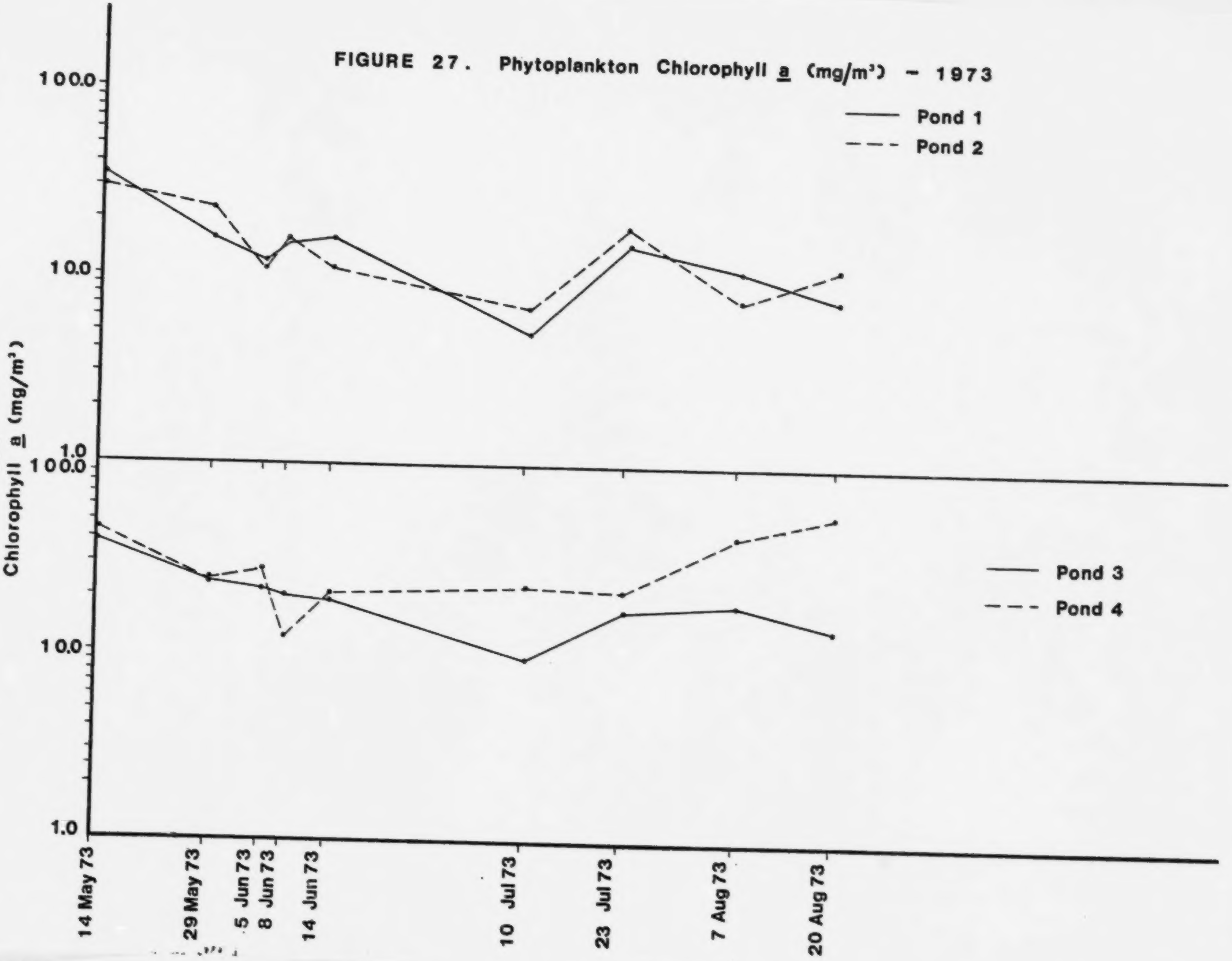


FIGURE 27. Phytoplankton Chlorophyll a (mg/m³) - 1973

values (Ponds 3-4) approached statistical significance which was the probable result of shifts in the number of species and number of individuals of the green algae, blue-green algae, and diatoms.

Regression analysis and covariance tests were unable to correlate chlorophyll a (mg/m^3) to numbers of individuals in the following combinations:

1) Pooled data from all four test ponds comparing total number of individuals/ml versus chlorophyll a, using a linear regression analysis and covariance.
2) Pooled data from all four test ponds comparing total number of individuals/ml exclusive of blue-green algae versus chlorophyll a, using a linear regression analysis and covariance.
3) Covariance test on each pond comparing ln total individuals/ml versus chlorophyll a.
4) Covariance test on each pond comparing ln total individuals/ml exclusive of the blue-green algae versus chlorophyll a.
5) Covariance test on each pond comparing ln total green algae/ml versus chlorophyll a.
6) Covariance test on each pond comparing ln total diatoms/ml versus chlorophyll a.

The three groups of algae were selectively tested for correlation because each has its predominant pigments, e.g., green algae - chlorophyll, blue-green algae - phycoerythrin, and diatoms - xanthophylls and carotenes(94). Natural logarithms (ln) of numbers of individuals were used in an effort to reduce the variance and standard deviation in the statistical tests. Table 34 indicates very low positive and most often, negative correlation, suggesting chlorophyll a (mg/m^3) decreases as population

TABLE 34

TEST OF COVARIANCE - CHLOROPHYLL a VS. NUMBERS OF INDIVIDUALS

Comparisons	Coefficient of Correlation Pond 1	 Pond 2	 Pond 3	 Pond 4
Total numbers excluding blue-green algae (lnN/ml)	-0.3585	-0.2506	-0.3399	0.7132
Total numbers (lnN/ml)	-0.3273	-0.2255	-0.7859	0.1480
Total diatoms	-0.4135	-0.4064	-0.5573	-0.2235
Total green algae (lnN/ml)	-0.2158	0.0141	-0.5742	0.3097

(number/ml) increases.

The significance of the variation in chlorophyll a levels between Ponds 3 and 4 (Pond 4 being greater) occurs after June 14, 1973 or after enumeration of species was discontinued. From this point in time the levels are divergent in these two test ponds with levels in Pond 4 increasing through August 20, 1973. Although the data from the 1973 collecting period shows a lack of correlation between chlorophyll a and numbers of individuals, this is contrary to findings in the literature(99). Visual observation of the test ponds suggested periodic bloom conditions in Pond 4 which would explain the increases in chlorophyll a levels if there was a positive correlation between the parameters. This was not examined microscopically yet provides a logical explanation of the variations. Without further testing, the variation of chlorophyll a levels in the test ponds must be explained as natural cyclic patterns of biological communities in isolated bodies of water.

Productivity Index - The productivity index values are given in Table 33. This index is calculated from ^{14}carbon productivity and chlorophyll a values derived from independent subsamples of the 1973 composite collections. Within pond-pairs the productivity index was similar which is further shown in Table 30. The mean value in Pond 1 was 1.05 (standard deviation = 0.76) and the mean value in Pond 2 was 1.06 (standard deviation - 0.89). This similarity was not as close in Ponds 3 and 4 where the mean value in Pond 3 was 1.07 (standard deviation = 0.88) and the mean value in Pond 4 was 0.54 (standard deviation = 0.86).

A two tailed paired t-test, 95 percent confidence level, showed the variations in the productivity index to be insignificant (Table 30). With this index higher values indicate greater photosynthetic efficiency, i.e., greater net conversion of carbon dioxide to organic carbon per unit of chlorophyll a. An index such as this is valuable in comparing different autotrophic communities, in toxicity studies of primary producers, or in photosynthetic inhibition studies(48). After finding differences in ^{14}carbon production which showed statistical significance during 1972 an effort was made to gather data which would relate to the toxic or inhibitory effects of outboard engine stressing if they existed under field-test conditions. The resulting productivity index data of 1973 showed no inhibitory or toxic properties caused by outboard engine stressing over an extended period of time (May 14, 1973 - August 20, 1973). Values in the control and non-leaded stress ponds were nearly identical while values in Pond 3 (leaded stress) were greater than its control (Pond 4). The derived values were similar to those calculated by Gunderson(48) for marine waters.

Photosynthetic Inhibition Around Engines - Although five experiments were conducted, sufficient data was collected only on two dates, June 31, 1973 and August 27, 1973; data from May 14, 1973 represent "prestart" data. Chlorophyll a, ^{14}carbon production, productivity index, and cell count data are presented in Tables 35-40. In all data there is a wide range of values. These data were analyzed for significance of variations with a paired t-test, 95 percent confidence level. Correlation coefficients were used to compare cell numbers (lnN/ml) with chlorophyll a (mg/m^3) and chlorophyll a (mg/m^3) with ^{14}carbon production (mg C/m^3/hr.)

TABLE 35

PRODUCTIVITY INHIBITION AROUND ENGINES - ^{14}Carbon Production

Date	Pond	Time Collected	From Dock	Submerged	Cooling Water
14 May 73	1	Before	0.971	0.199	
	3	Before	0.037	0	
31 May 73	1	Before	5.783	7.398	
		During	6.881	8.318	7.423
	3	Before	10.890	11.912	
		During	10.944	12.178	11.076
27 Aug 73	1	Before	5.767	6.829	
		During	6.209	5.593	4.916
	3	Before	7.528	14.114	
		During	9.209	6.124	3.901

TABLE 36

PRODUCTIVITY AROUND ENGINES - CELL COUNTS (no./ml)

Date	Pond	Time Collected	From Dock	Submerged	Cooling Water
25 May 73	1	Before	10,454	17,211	
		During	13,876	14,012	10,633
	3	Before	10,407	10,993	
		During	11,308	13,786	16,354
31 May 73	1	Before	10,993	12,660	
		During	10,768	8,605	7,524
	3	Before	22,032	15,675	
		During	18,247	22,288	20,320

Table 37. MEAN CELL COUNTS (no./ml)

Date	Pond	Before Engine Run	During Engine Run	Cooling Water
25 May 73	1	13,833	13,944	10,633
	3	10,700	12,547	16,354
31 May 73	1	11,827	9,687	7,524
	3	18,854	20,268	20,320

Table 38. PRODUCTIVITY INHIBITION AROUND ENGINES
Chlorophyll a (mg/m^2)

Date	Pond	Time Collected	From Dock	Submerged	Cooling Water
14 May 73	1	before	22.040 30.464	40.600 38.860	
	3	before	35.394 38.397	35.698 45.703	
31 May 73	1	before	28.514 24.055	33.060 23.848	
		during	33.299 24.044	28.731 30.685	22.315 25.577
	3	before	36.116 34.148	36.017 38.431	
		during	38.659 25.718	38.715 39.855	40.606 38.508
27 Aug 73	1	before	10.330 6.633	21.175 18.998	
		during	16.355 15.485	17.898 15.999	10.917 10.931
	3	before	7.786 6.691	27.859 27.489	
		during	14.977 12.108	15.899 16.334	11.500 11.448

TABLE 39

PRODUCTIVITY INHIBITION AROUND ENGINES - Productivity Index

$$\frac{\text{mgC/m}^3\text{/hr}}{\text{mg Chl } \underline{a}\text{/m}^3}$$

Date	Pond	Time Collected	From Dock	Submerged	Cooling Water
14 May 73	1	before	0.037	0.005	
	3	before	0.001	0	
31 May 73	1	before	0.22	0.26	
		during	0.24	0.28	0.31
	3	before	0.31	0.32	
		during	0.34	0.31	0.28
27 Aug 73	1	before	0.68	0.34	
		during	0.39	0.33	0.45
	3	before	1.04	0.51	
		during	0.68	0.38	0.34

TABLE 40

MEAN PRODUCTIVITY INDEX

Date	Pond	Before Engine-Run	During Engine-Run	Cooling Water
31 May 73	1	0.24	0.26	0.31
	3	0.32	0.33	0.28
27 Aug 73	1	0.51	0.36	0.45
	3	0.78	0.53	0.34

With the minimum amount of data collected the significance of correlations and variations was difficult to determine. The following statistical tests were applied to the data:

1. Paired t-test, 95 percent confidence level
    a) Chlorophyll a (mg/m^3)
    b) ^{14}Carbon production (mg C/m^3)
    c) Productivity Index
2. Coefficient of correlation, 95 percent confidence
    a) Cell counts (lnN/ml) versus Chlorophyll a (mg/m^3); before and during engine runs, and cooling water.
    b) Chlorophyll a (mg/m^3) versus ^{14}carbon production (mg C/m^3/hr);

        From dock before engine-run
        Submerged before engine-run

        From dock during engine-run
        Submerged during engine-run
        Cooling water

        From dock and submerged before engine-run
        From dock and submerged during engine-run

Due to small sample size the paired t-test was considered valid only for chlorophyll a measurements which contained many data points. The results of this test are provided in Table 30. Two significant variations (95 percent confidence level) were observed, both involving collections from the surface waters around the dock. In Pond 1 chlorophyll a levels were significantly greater during engine-run (mean = 25.77 mg/m^3) than before engine-run (mean = 17.82 mg/m^2). Standard deviations were 8.72 and 7.46 respectively. In Pond 3 chlorophyll a levels were significantly greater in the cooling water than in the surface water from around the test engine-dock before engine-run. Mean and standard deviation were 26.34 and 11.52 in the cooling water and 23.00 and 11.06 in the surface waters before engine-run.

When correlation was drawn between chlorophyll a and cell counts (lnN/ml) only one comparison had a significant, positive correlation. The positive combination was in the samples collected before engine-run which involved 16 data points; the level of significance was 0.590 with a calculated value of 0.832. Sixteen data points compared from the pooled samples during engine-run yielded a calculated level of 0.551; less than the 0.59 significance level at 95 percent confidence. The cooling water had the lowest correlation (0.364) with eight data points and a critical value of 0.795.

Of the seven comparisons made between chlorophyll a and ^{14}carbon production, three showed significant, positive correlation. Table 41 shows the correlations between chlorophyll a and ^{14}carbon production that were determined.

The data indicate greater chlorophyll a in the cooling water and during engine-run than before engine-run from surface waters around the dock. A possible hypothesis is that there was stratification of organisms and that the turbulence of engine-runs mixed the waters, resuspending more organisms. However, correlation of pooled data, cell counts (lnN/ml) against chlorophyll a showed high correlation (0.832) in the samples from before engine-run, low correlation (0.551) during engine-run, and very low correlation (0.364) in the cooling water. Temperature measurements revealed a Δt of 10°C-15°C from ambient (15°C-18°C) in the cooling water of the test engines. The low cell count to chlorophyll a correlation in the cooling water samples plus the significantly greater chlorophyll a levels found in the cooling water is not completely understood. The temperature shock of passing through the outboard engine

TABLE 41

Correlation of Chlorophyll a (mg/m^3) to ^{14}Carbon Production

Collection	Correlation Coefficient	F Value 95% Confidence Level
Surface water around test dock before engine-run	0.602	0.795
Submerged before engine-run	0.501	0.795
Surface waters around test dock during engine-run	0.333	0.795
Submerged during engine-run	0.973*	0.795
Cooling Water	-0.139	0.795
Pooled data from surface and submerged waters before engine-run	0.591*	0.590
Pooled data from surface and submerged waters during engine-run	0.691*	0.590

* Significant positive correlation

cooling system may have damaged or weakened the cell walls and cell membranes of the phytoplankton. This could have increased the efficiency of the extraction solvent; cells were not mechanically mascerated for pigment extraction. If this did occur then greater amounts of chlorophyll a would have been recorded and a higher correlation would have been determined from the cooling water samples.

Although variations of the productivity index could not be tested due to small sample size, the coefficient of correlation between chlorophyll a and ^{14}carbon production did show significance. Correlation was good in the before engine-run (0.591) and during engine-run (0.691) tests; critical F value being 0.590. Correlation was very bad (-0.139) in the cooling water, and very good in the submerged samples (0.973) during engine-run; critical F values being 0.795.

The apparent conclusion is that no significant effect on primary production could be detected in the immediate vicinity of the test engines. However, there was a localized effect in the cooling water where there was a negative correlation between chlorophyll a and ^{14}carbon production. Mean productivity index values (Table 40) show greater net carbon fixation per unit chlorophyll a in six of eight combinations where the cooling water had the lowest values. Mean cell counts were not extremely different in comparing samples from before engine-run, during engine-run, and cooling water. These differences were not determined to be significant and further testing is required to draw more definitive conclusions.

Zooplankton

Samples taken on 11 dates during the 1972 study season were counted and all taxanomic data are reported in Appendix C_{23}. Appendix C_{24} is a listing of all the biological indicies calculated from this data. The zooplankton population of the four test ponds consists predominately of rotifers of the family Brachionidae, Table 42 illustrates this dominance. Further, the taxon Keratella cochlearis demonstrated the greatest percent abundance relative to all other net-zooplankton on 55 percent of the dates sampled in one of the control sections (Pond 2) and in both of the stressed ponds (1 and 3). Keratella cochlearis was the most abundant organism within the zooplankton community sampled on 36 percent of the collection dates in Pond 4 (control section). In Pond 1 (non-leaded stress section) animals of the family Brachionidae dominated the total community on 91 percent of the dates sampled (10 days). Polyarthra sp., a member of the Synchaetidae dominated on the remaining 9 percent of the dates (one day). At no time during the 1972 sampling season did a population of organisms other than the rotifers dominate the collection of net-zooplankton. Conversely, Pond 2 (control cell) was dominated on 18 percent of the dates by the Rhizopod, Difflugia sp. A predominantly benthic animal, this organism enters the water column in late summer and is therefore classified as "animal-limnoplankton" or zooplankton. Difflugia sp. also dominated the zooplankton community sampled in Pond 3 (leaded stress section) on 18 percent of the collection dates and in Pond 4 (control section) 36 percent of the time. On August 2, 1972 568 copepod nauplii were taken from Pond 4, these nauplii represented 56 percent of the total net zooplankton taken

TABLE 42

1972 MEAN PERC$\underline{E}$NT ABUNDANCE OF THE ROTIFERA AND FAMILY BRACHIONIDAE

Mean Percent ($\bar{X}$) Abundance of the Rotifera and Family Brachionidae
Compared to All "Other" Net-Zooplankton Collected

	Pond 1	Pond 2	Pond 3	Pond 4
Taxa	Mean ($\bar{X}$)Percent Abundance			
Rotifera	91.5	81.5	78.5	62.4
Brachnionidae	76.5	62.5	69.5	53.7
"Others"	8.5	18.5	21.5	37.6

in Pond 4 on that date.

A bloom which was observed in September of 1972 was due primarily to Brachionus angularis in all test ponds except Pond 4, see Table 43.

Table 43 also illustrates that K. cochlearis maintained the peaks in total numbers of net-zooplankton and demonstrated a lag growth period subsequent to B. angularis. The lag period was evident only in the initial community pulse of September 22, 1972, which began the period of highest concentration per unit volume of net-zooplankton collected during that year. There was no disproportionate pulse in total numbers of net-zooplankton during 1972 associated with Pond 4 (see Figure 29 and Figure 32). Further, upon analysis of Table 43 no increase in B. angularis or K. cochlearis in Pond 4 can be associated with this time period. This control cell (Pond 4) also demonstrated the lowest percent abundance of the rotifers although they remained the dominant forms.

Zooplankton species richness ($S/\sqrt{N}$) for 1972 indicates patterns of community fluctuation. The richness of total net-zooplankton dropped from 0.30 on September 15, 1972 to 0.03 on September 22, 1972 in Pond 1, and from 0.46 to 0.14 in Pond 2 on the same dates. Correspondingly, Pond 3 demonstrated a lower richness while the converse is true in Pond 4. It should be noted here that total numbers increased sharply during this time period in Ponds 1,2, and 3 while in Pond 4 the total numbers did not increase significantly.

TABLE 43

POPULATION DYNAMICS OF NET - ZOOPLANKTON COMMUNITY - SEPTEMBER 1972

Population Dyanmics of *B. angularis* and *K. cochlearis* as related to total net-zooplankton community structure

	22 September 1972				29 September 1972			
Taxa	1	2	3	4	1	2	3	4
Brachionus angularis	1184	3160	216	8	1000	3024	2560	0
Keratella cochlearis	120	520	24	8	2968	1760	1484	472
Total net-zooplankton	1496	4232	322	40	5034	5664	4828	568
Total number of taxa	8	9	5	5	13	11	10	5

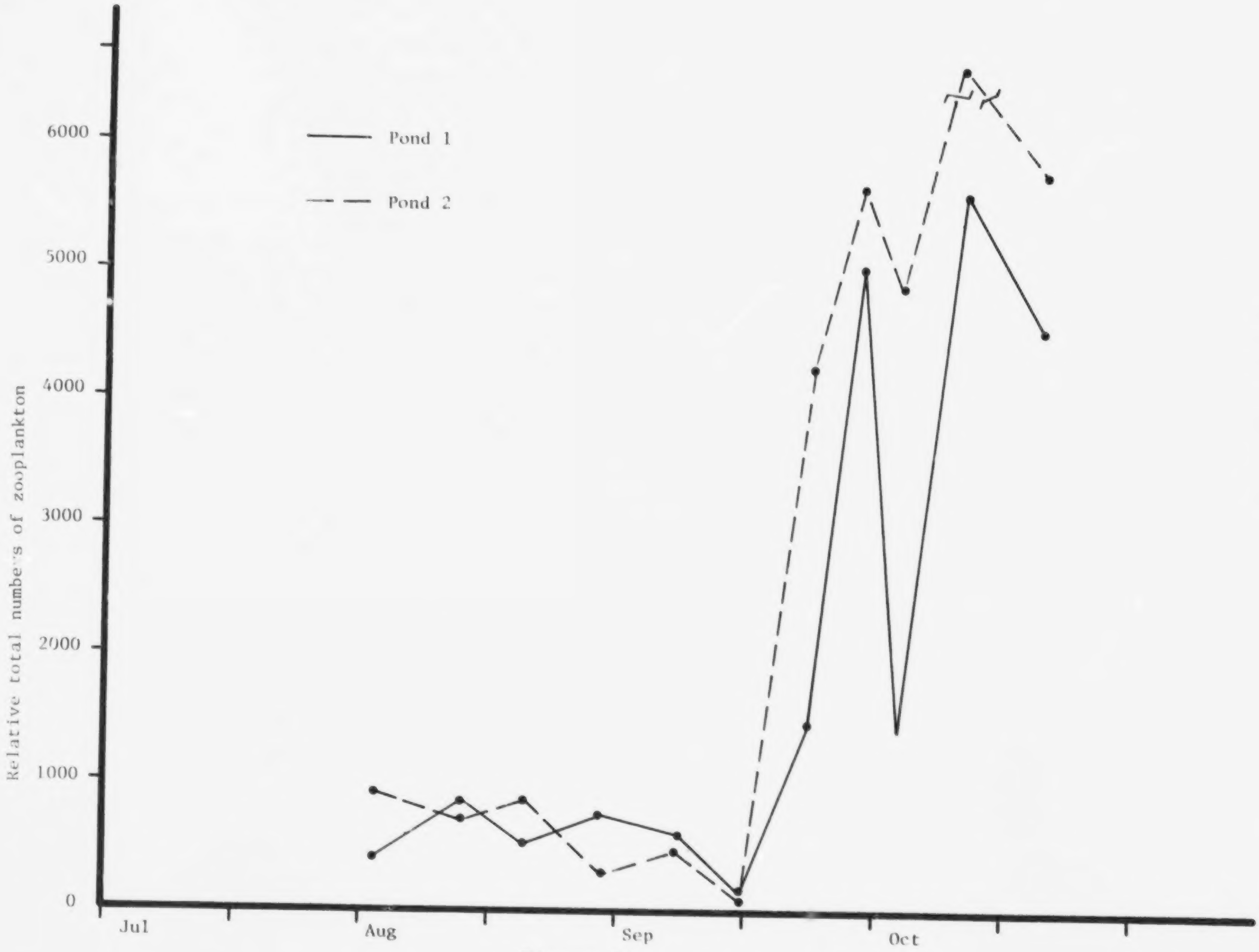


Figure 28

Zooplankton Population Dynamics 1972

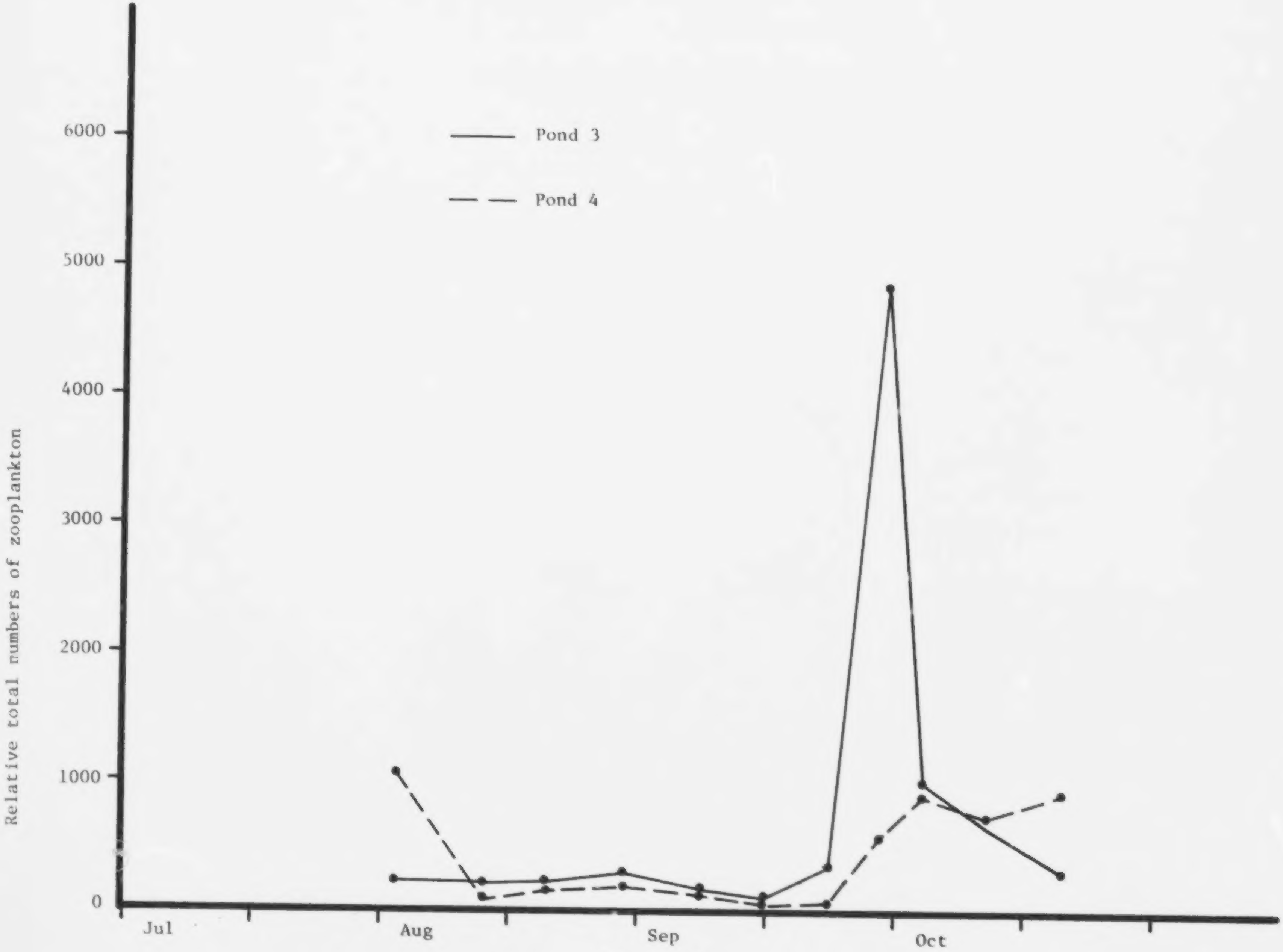


Figure 29

Zooplankton Population Dynamics 1972

The data derived from the zooplankton richness index indicate general paired-pond seasonal fluctuation patterns. There was, in Pond 1 and 2, a decline in richness between the sampling dates of August 18, 1972 and August 28, 1972, this was associated with only a slight change in total individuals collected in Pond 1. However, there was a radical reduction, not only in number of species, but also in the number of individuals collected in Pond 2 during these dates as shown in Table 44. Richness in Pond 3 and Pond 4, when compared by net-zooplankton, demonstrated a similar lag effect from August 2, 1972 through August 18, 1972. Concurrent with this decline in community richness was a decline in both total individuals and species collected in Pond 4 and a decline in the number of species in Pond 3. An increase in richness during the period of August 18, 1972 to August 28, 1972 was evident, as was an increase in numbers of taxa taken from both Pond 3 and 4 (Table 45).

Numerical expressions of similarity between Ponds 1 and 2 showed these ponds to be more than 50 percent similar on all sampling dates, while Pond 3 and 4 achieved this level of similarity of species on 91 percent of the days sampled. Table 46 shows mean ($\overline{X}$) values of Sorenson's coefficient for the 1972 collection period.

All taxanomic data for the 1973 net-zooplankton are listed in Appendix C_{25}. Data derived from the various mathematical indicies are shown in Appendix C_{26}. The 1973 zooplankton data is quite similar to the 1972 zooplankton data in all areas except total numbers (Figure 32). The percent abundance of the

Table 44. POPULATION DYNAMICS AS RELATED TO NET-ZOOPLANKTON RICHNESS - AUGUST 1972

	18 August 1972		28 August 1972	
	Pond 1	Pond 2	Pond 1	Pond 2
Total numbers of individuals	532	880	748	320
Total number of species	10	11	4	6
Richness (S-1/lnN)	1.43	1.47	0.45	0.87
Dominant Taxa	*B.calyciflorus*	*K.cochlearis*	*K.cochlearis*	*Difflugia* sp.
Percent Dominance	55	65	57	31

Table 45. ZOOPLANKTON RICHNESS AS COMPARED TO PERCENT TAXA INCREASE - AUGUST 1972
Richness as Compared to Percent Taxa Increase In a Paired - Pond
(Leaded Stress versus Control) Situation - Time Period
August 18 - August 28, 1972

Percent Increase	Leaded Stress Pond	Control Pond
Richness	30	21
Taxa	38	33
Total Individuals		
August 18, 1972	180	128
August 28, 1972	252	168

Table 46. MEAN VALUES OF SORENSON'S SIMILARITY COEFFICIENT - ZOOPLANKTON COMMUNITY
(AUGUST TO OCTOBER 1972)
Mean ($\overline{X}$) Values of Sorenson's Similarity Coefficient
August 2 - October 16, 1972
0.50 = 50 percent Co-occurence of Taxa

	Pond 1 and 2	Pond 3 and 4
$\overline{X}$ value	0.76	0.70

Table 47. 1973 MEAN PERCENT ABUNDANCE OF THE ROTIFERA AND FAMILY BRACHIONIDAE
Mean ($\bar{X}$) Percent Abundance of the Rotifera and Family Brachionidae
Compared to All "Other" Net-Zooplankton

	Pond 1	Pond 2	Pond 3	Pond 4
Rotifera	78.5	75.9	81.9	89.1
Brachionidae	65.4	59.4	75.3	79.7
"Others"	21.5	24.1	18.1	10.9

Table 48. DOMINANT ZOOPLANKTON SPECIES - 1973

Taxa	Pond 1	Pond 2	Pond 3	Pond 4
Brachionus angularis	X			X
B. calyciflorus	X	X	X	
Polyarthia sp.	X	X	X	
Difflugia sp.	X		X	

X = occurred as dominant form during 1973 study period

Rotifera versus other zooplankton organisms is shown in Table 47. In 1973 the ponds designated 1 and 2 (non-leaded stress and its control section) demonstrate a reduced abundance by the Brachionidae, while the leaded test section (Pond 3) and its associated control (Pond 4) both exhibited an increase in percent abundance by Brachionid taxa over the 1972 sampling period. The Brachionid *Keratella cochlearis* was the dominant zooplanktonic form, mean ($\bar{X}$), in all ponds during the 1973 study season. *K. cochlearis* dominated on 50 percent of the days sampled in Pond 1, 60 percent in Pond 2, 60 percent in Pond 3, and 70 percent in Pond 4. Other significant taxa which dominated at various times during 1973 may be found in Table 48.

The total number of net-zooplankton collected during the 1973 phase of the survey were greater than those taken in 1972. However, the same trends and fluctuations were observed for both years (see Figures 28, 29, 30, 31, and 32). The two "paired-pond" (test/control) sections were approximately one month out of phase when compared on a "total individuals" recovered basis. The species richness, calcualted by the expressions, $S/\sqrt{N}$ and $S-1/\ln N$,of the zooplankton community was reduced in 1973 when compared to 1972. This effect carried throughout all ponds and was concominant with population trends. The similarity of the non-leaded stress pond versus its associated control pond achieved values of 50 percent on every date sampled. The leaded stress versus its control demonstrated greater than 50 percent similarity of taxa on 90 percent of the collection dates. Mean ($\overline{X}$) values were 0.79 and 0.72 for Pond 1 versus Pond 2 and Pond 3 versus Pond 4, respectively. The only

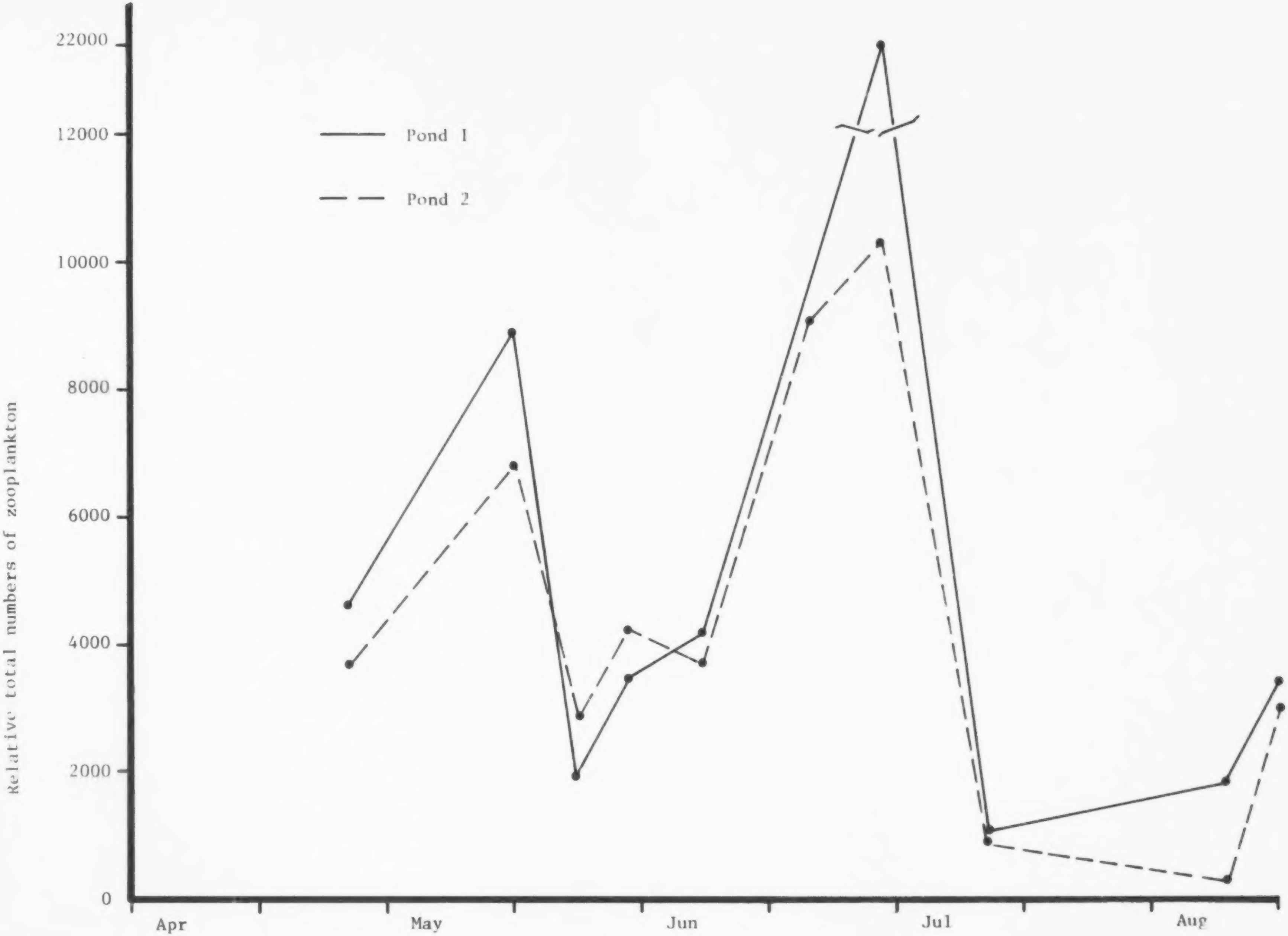


Figure 30

Zooplankton Population Dynamics 1973

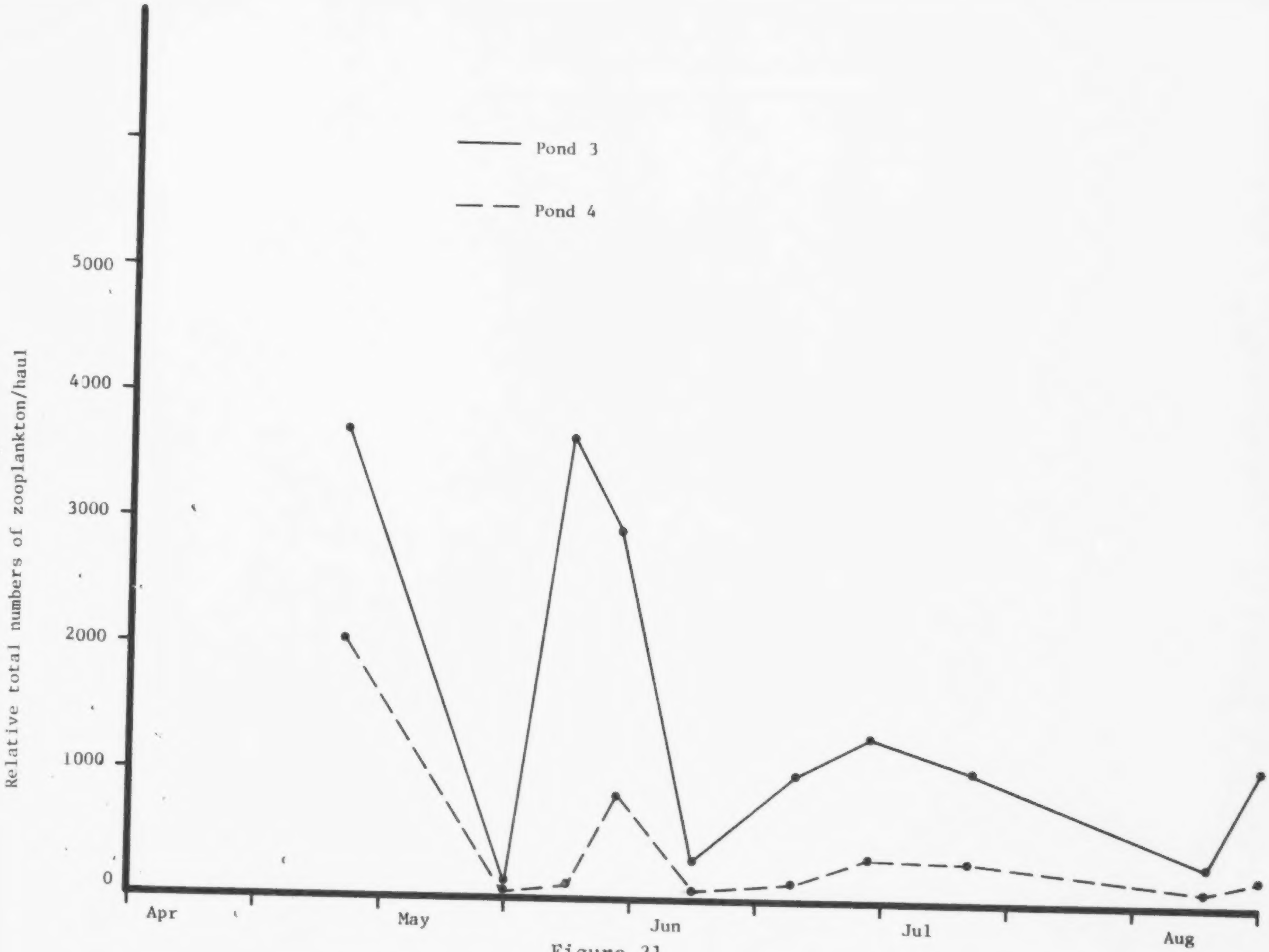
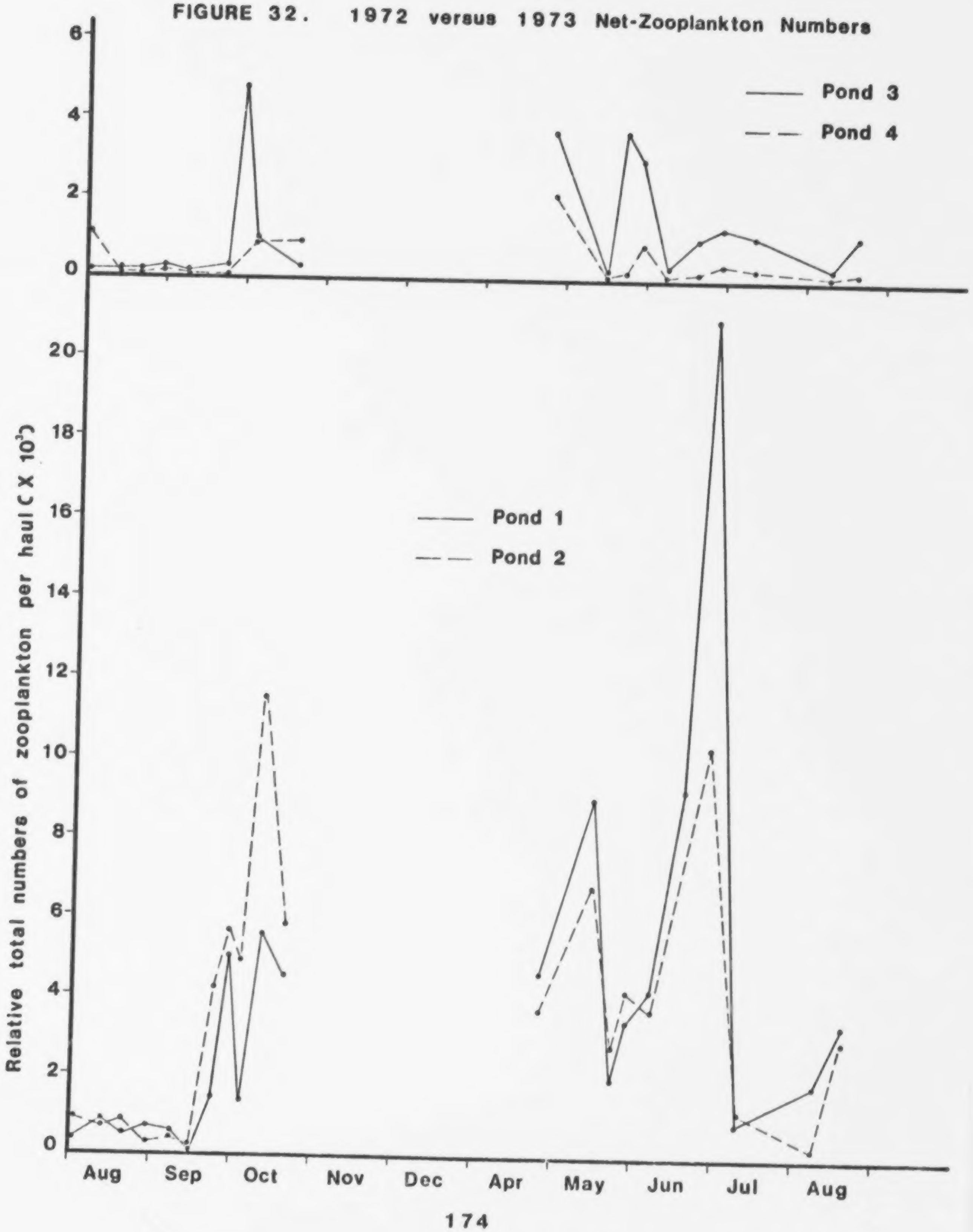


Figure 31

Zooplankton Population Dynamics 1973

FIGURE 32. 1972 versus 1973 Net-Zooplankton Numbers



significant alteration in community structure between 1972 and 1973 was the addition of two taxa, both calanoid: Senecella calanoides and Diaptomus sp., and the increased relative numbers of net-zooplankton collected in 1973.

The predominance of the Rotifera in the four ponds demonstrates the common microplanktonic fauna of ponds and small lakes Ruttner(100). The first appearance by the Rhizopod Difflugia sp. in late summer is also a normal phenomena, Hutchinson(95), and Edmondson(72). The sporadic occurance of the various Crustacea encountered during the study is considered normal. Within the Rotifera only one specie normally dominated the zooplankton. Pennak(65) also reported such a situation. Ruttner(100) indicates this is due to competition, especially with respect to food, among those organisms with similar requirements. The Brachionids Keratella cochlearis and Brachionus angularis were the prime dominant forms within the test ponds and, as these organisms have very similar niche requirements, one would have to reduce in total numbers before the other could become the dominant form. In Pond 4 no abnormal pulse of total numbers of net-zooplankton was observed, this is coupled with the fact that no extremes in either of these species of Brachionidae occurred in this pond. The relatively high species richness ($S/\sqrt{N}$) in Pond 4 was due to the lowered dominance by the Rotifera; i.e., more microhabitat remained available for other forms of zooplankton. Further, Pond 4 had a 56 percent dominance by nauplii in August of 1972. It is assumed that when many of these larval copepods reached maturity they grazed upon, among other foods, the Rotifera. According to numerous authors, Edmondson(64), Pennak(65), Reid(83), Hutchinson(95), Ruttner $^{(100)}$, and others, the crustaceans migrate with respect to such factors as temperature, dissolved oxygen and light intensity. As all samples were taken at approximately the same time (1300 hours) and the light intensity would be highest at this time the crustaceans would be at a greater depth than the depth that the net-tow could sample at under a velocity of 0.8 m/sec. Upon application of the paired "t" statistical test (Table 49) only one significant variation occurred for richness ($S/\sqrt{N}$). That was when Pond 3 was compared with Pond 4 in 1973. With a compared mean ($\overline{X}$) of 0.15 and 0.25 for Ponds 3 and 4, respectively, and nine degrees of freedom the calculated "t^2_s" value was 18.84 while the tabulated critical value was 7.21, with a standard deviation of 0.13. This significance occurred because Pond 3 had higher total numbers of net-zooplankton than Pond 4 but more importantly, these greater numbers within the collections were confined primarily to the Brachionid Rotifera; this served to reduce the calculated diversity of Pond 3. Further, according to Ruttner$^{(100)}$, variations of 10 or 20 percent have no significance in plankton statistics. Overall, net-zooplankton populations demonstrated normal ecological dynamics during the study.

Benthos

The 1971 benthos species composition data is summarized in Appendix C_{27}, while individual calculations of Shannon Weaver diversity and richness ($S-1/\ln N$) on these samples are given in Appendix C_{28}. To evaluate the composition of each pond the three samples collected from each pond during each sampling period were pooled. Richness and Shannon Weaver diversity have also been calculated on these

Table 49. ZOOPLANKTON STATISTICS
Paired t-Test - 95 percent Confidence Level

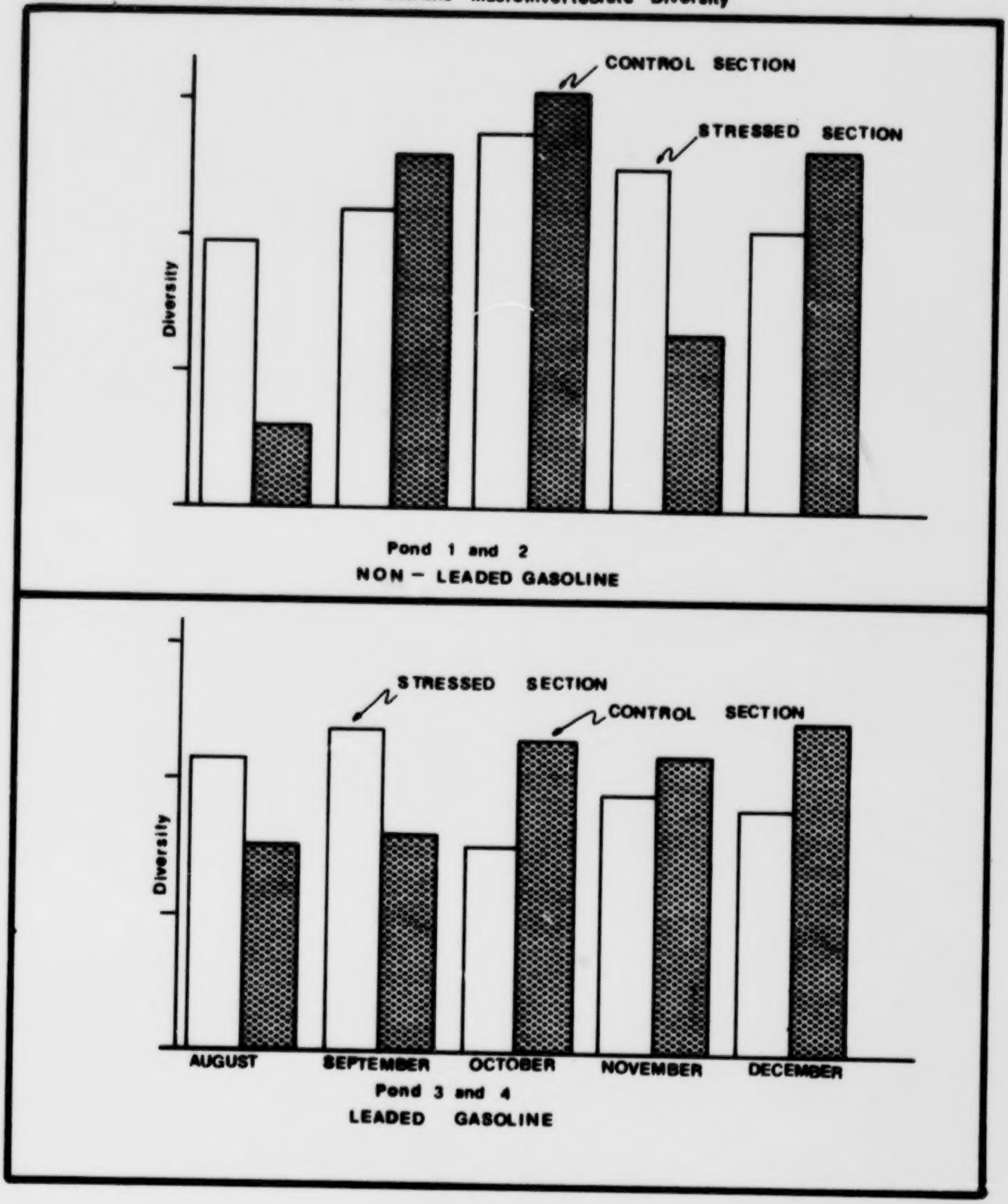
Parameter	Year	Test Ponds	df	$\overline{Y}$	$S_{\overline{Y}}$	$\overline{X}$	$S_{\overline{X}}$	F value	t_s	t^2_s	sig.
Richness $\frac{S}{\sqrt{N}}$	1972	1 vs. 2	10	0.23	0.16	0.26	0.14	6.94	0.94	0.88	
	1973	1 vs. 2	9	0.11	0.06	0.12	0.09	7.21	0.97	0.94	
	1972	3 vs. 4	10	0.32	0.17	0.41	0.24	6.94	1.64	2.69	
	1973	3 vs. 4	9	0.15	0.08	0.25	0.13	7.21	4.34	18.84	*
Richness S-1/lnN	1972	1 vs. 2	10	1.02	0.39	1.18	0.29	6.94	1.91	3.65	
	1973	1 vs. 2	9	0.66	0.34	0.65	0.33	7.21	-0.25	0.06	
	1972	3 vs. 4	10	0.83	0.34	0.94	0.46	6.94	1.11	1.23	
	1973	3 vs. 4	9	0.52	0.36	0.49	0.45	7.21	-0.61	0.37	

"pooled" samples and are tabulated in Appendix C_{29}. Figures 33 and 34 contrast Shannon Weaver diversity and biomass on the benthic populations in the four experimental ponds during 1971.

The first two sampling dates, August and September, 1971, can be considered quantitative controls since all samples were collected prior to stressing any of the ponds with exhaust emissions from outboard engines. In general, richness values (S-1/lnN) within each "pair" of ponds (1 and 2, 3 and 4) were quite similar in September before treatment began (see Appendix C_{29}). After outboard engine stressing was initiated, Pond 1 (non-leaded stress section) had higher richness values during October and November than its associated control (Pond 2). In December this trend was reversed and Pond 2 (control) showed a higher richness value than Pond 1 (Appendix C_{29}).

The leaded fuel stress section (Pond 3) and its associated control section (Pond 4) were almost identical in richness during August and September of 1971 as shown in Appendix C_{29}. However, after outboard engine stressing began richness decreased in Pond 3 and remained lower than the control section (Pond 4) during the remaining months of 1971. A review of Appendices C_{28} and C_{29} and Figure 33 show similar trends in Shannon Weaver diversity values except that Pond 3 had a higher diversity prior to outboard engine stressing than its control. After stressing began the diversity of Pond 3 dropped below the diversity level of Pond 4 for the remainder of 1971. This situation was reversed during 1972 when the diversity of Pond 3 was higher than the diversity of Pond 4 approximately 60 percent of the time (see Appendix C_{32}).

FIGURE 33. 1971 Benthic Macroinvertebrate Diversity



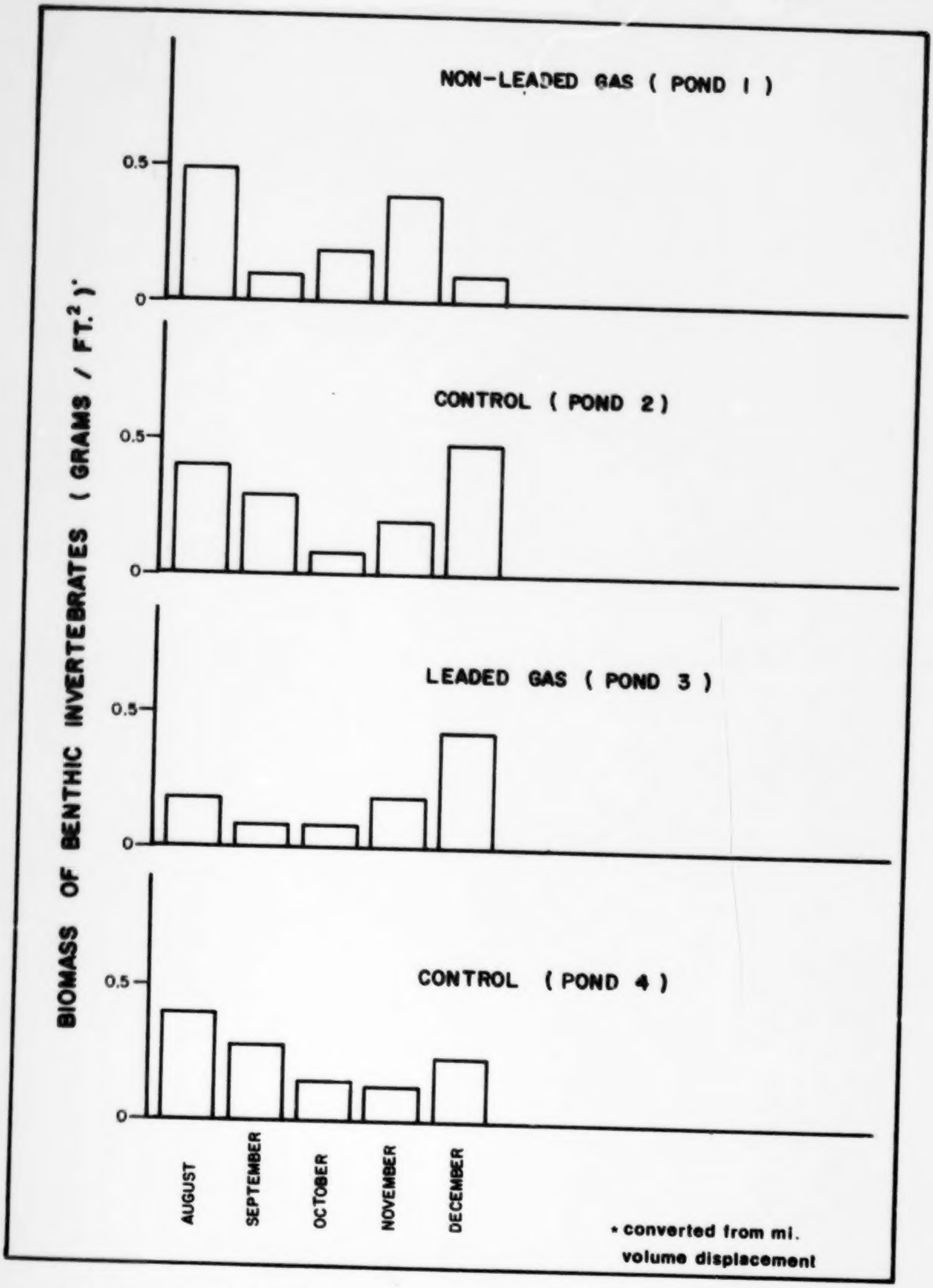


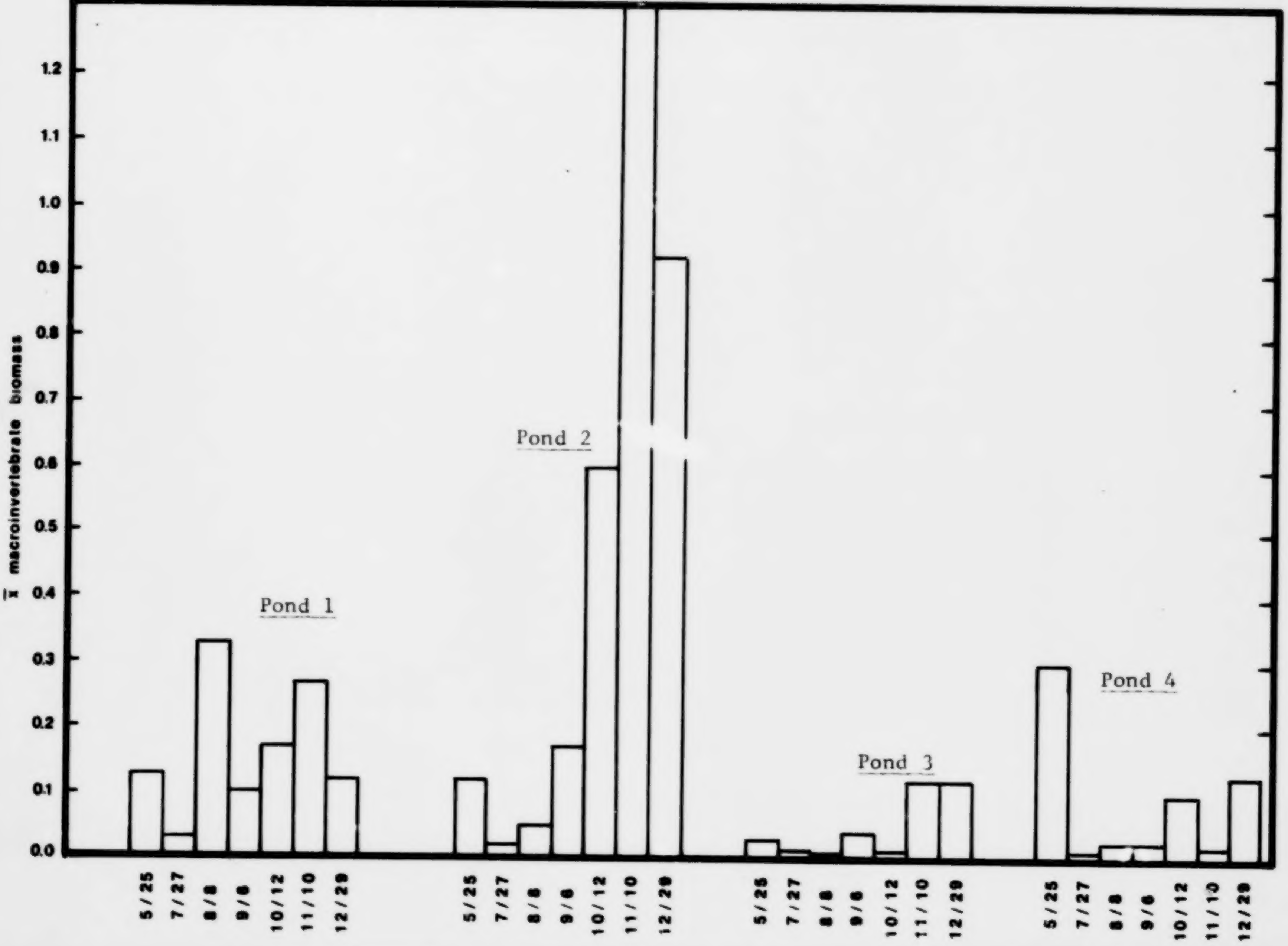
Figure 34 - 1971 Macroinvertebrate Biomass

The benthic biomass (1971) of animals present in each pond is presented in Appendix C_{30} and shown graphically in Figure 34. There was a general decline in biomass in all ponds from August through October and then an increase through December, with the exception of the non-leaded test section (Pond 1) in December.

Seven sets of benthic samples were taken and analyzed during 1972. The biomass of the macroinvertebrate assemblage was calculated by volume displacement and species composition of each sample was determined. These data are presented in Appendix C_{31} and shown graphically in Figure 35. As in 1971, all 1972 samples taken from a given pond on each sampling day were analyzed individually (see Appendix C_{31}). However, Shannon Weaver diversity and richness values were calculated based on "pooled" samples from each pond. Diversity and richness results on the benthic community during 1972 are shown in Appendices C_{32} and C_{33}.

A review of Appendix C_{33} shows that the macroinvertebrate richness, as measured by the formula $S/\sqrt{N}$, of Ponds 1 and 2 was similar throughout the seven month sampling period of 1972 and only on two dates did the richness of the control pond achieve a higher value than the non-leaded stress pond,(August 8 and September 6, 1972). A similar trend in richness ($S/\sqrt{N}$) was noted when the leaded pond was compared to its control section. Richness measured by the formula ($S-1/\ln N$) of benthic forms in Pond 1 and 2 were quite similar throughout the sampling period (See Appendix C_{33}). However, during August and September the control section (Pond 2) exhibited a

FIGURE 35. $\bar{X}$ Macroinvertebrate Biomass 1972



higher richness than the test section (Pond 1). Ponds 3 and 4, leaded test and control sections, respectively, showed a similar trend in regard to both richness values (S-1/lnN and $S/\sqrt{N}$) as the comparison between Ponds 1 and 2.

During the 1971 study period diversity values showed a definite decrease in both of the stressed sections (Ponds 1 and 3). No such effect on benthic diversity of the test sections was observed in 1972 (See Appendix C_{32}). The biomass of benthic macrofauna observed during 1972 is presented in Appendix C_{31} and shown graphically in Figure 35. There was a general decline in biomass in Ponds 1 and 2 from May to July with an increase in biomass from July through November. In December of 1972 biomass in both Ponds 1 and 2 showed a slight decrease. Although similar trends were observed in Ponds 3 and 4 during the 1972 study period, the degree of biomass flucuation was minimal and of relatively minor significance.

In 1973 the benthic macroinvertebrate community was surveyed four times, these data are presented in Appendix C_{34}. The total numbers, as well as number of taxa collected from all ponds were greatly reduced during the 1973 macroinvertebrate sampling period (See Figure 36). In 1972 mean ($\bar{X}$) biomass numbers for Ponds 1,2,3, and 4 were: 0.16, 0.05, 0.47, and 0.11, respectively. The mean ($\bar{X}$) biomass data for 1973 for Ponds 1,2,3, and 4 were 0.11, 0.21, 0.02, and "negligible", respectively. Richness values calculated on the 1973 benthos collections are presented in Appendix C_{35}. Richness as measured by the expression ($S/\sqrt{N}$) indicates an abrupt decrease in all ponds on July 24, 1973 except for Pond 2 (See Figure 37). This control section (Pond 2) demonstrated a decrease in richness on June 18, 1973. There was an increase, then, in richness of all four ponds during the period from July 24 to August 23, 1973. All ponds demonstrated fairly similar

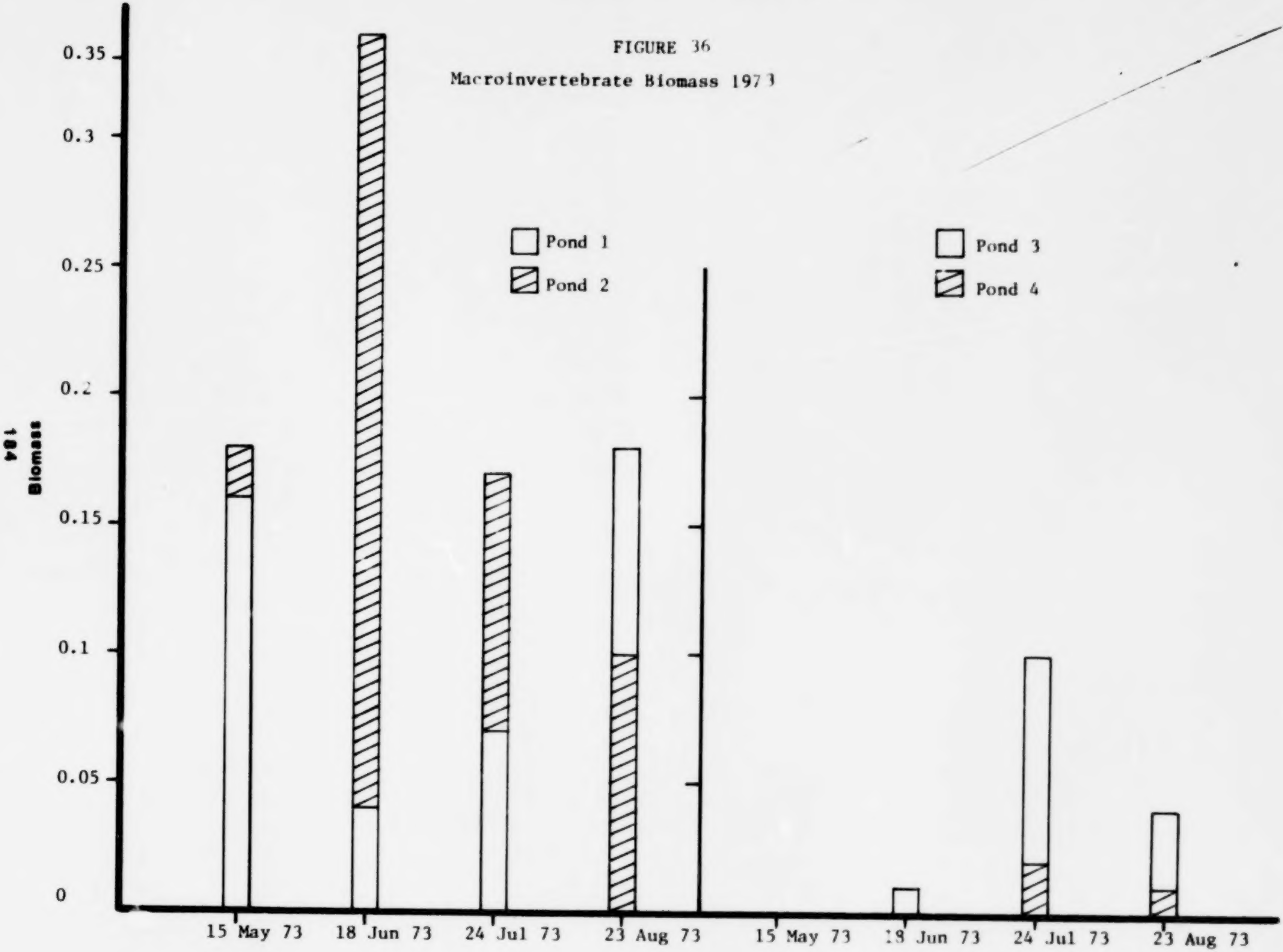
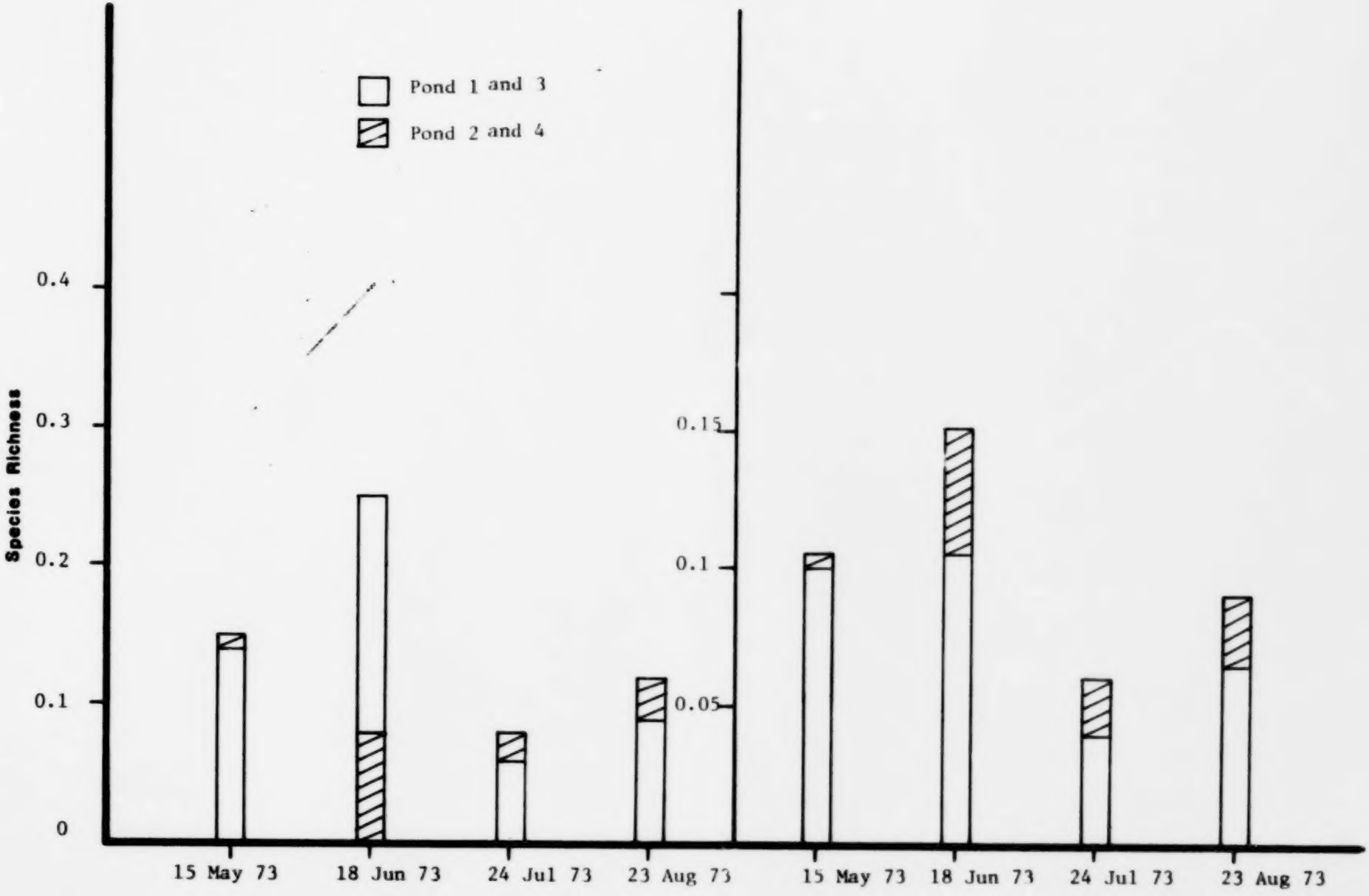


FIGURE 36

Macroinvertebrate Biomass 1973

FIGURE 37

Macroinvertebrate Species **Richness** $(S/\sqrt{N})$ 1973



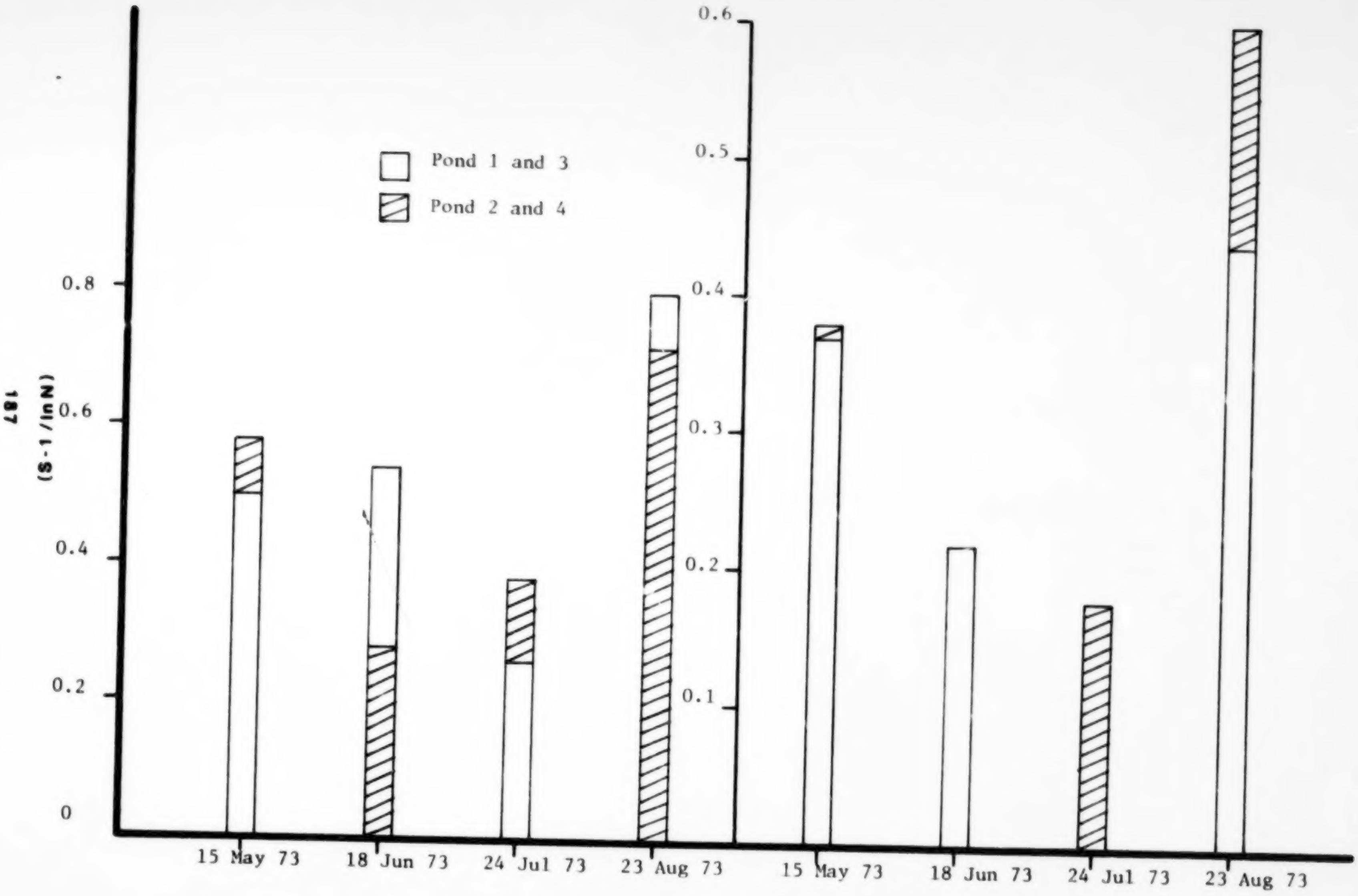
trends in species richness ($S/\sqrt{N}$) during 1973. Ponds 2, 3 and 4 had a decrease in richness ($S-1/\ln N$) on June 18, 1973 while the non-leaded stress section (Pond 1) had a slight increase in macroinvertebrate richness on that date. Both stressed ponds (Ponds 1 and 3) demonstrated a decrease richness on July 24, 1973 and all four ponds increased to their highest richness values on the subsequent August survey (Figure 38).

Biomass of benthic macrofauna in Pond 2 increased sharply from 0.18 mls displaced on May 15th to 0.37 mls displaced on June 18, 1973, this was concurrent with a reduction in species richness ($S-1/\ln N$) from 0.57 to 0.28 while the total number of organisms in Pond 2 increased from 1083 on May 15th to 1368 individuals per square meter on June 18, 1973. This population shift was the result of the loss of two species and the increased abundance of *Chironomus tentans* on June 18, 1973. On this same date (June 18, 1973) Pond 1 demonstrated a decreased biomass (0.16 - 0.04 mls displaced) (See Figure 36), with an increase in richness from 0.5 to 0.54 (See Figure 38). The total number of organisms per square meter on June 18, 1973 in Pond 1 was 266, of which, 78 percent of these were *Chironomus tentans*. Both Ponds 3 and 4 (leaded stress and its control) showed greatly reduced biomass values when compared to Ponds 1 and 2. These ponds (3 and 4) began the 1973 season with a biomass value of less than 0.01 mls displaced (Figure 36) and followed similar trends throughout 1973. Pond 3 had a greater biomass than its associated control on all sampling dates.

The reported variations within the benthic macroinvertebrate

FIGURE 38

Macroinvertebrate Richness Component $(S-1/1_{n}N)$ 1973



community are considered to be due to normal population shifts. Shannon-Weaver diversity calculations on the 1971 data indicate a rather diverse (2.30, 2.04, 1.95 and 2.02) for Ponds 1, 2, 3, and 4 respectively) benthic faunal assemblage (See Figure 33). Shannon-Weaver diversity values for the ponds during subsequent years (1972 and 1973) indicated lower species diversity of benthic macrofauna in all ponds - See Appendices C_{32} and C_{36}.

This reduction in species diversity after 1971 was due to a shift in population which occurred in May 1972 in all ponds. This shift was due to normal trophic succession found in most bodies of water and accelerated here because of the small size of the test cells. Benthic organisms occupy a specific microhabitat which is dictated, in part, by their individual needs. The diverse assemblage in 1971 was due to the dominance of the green alga Chara sp. in all four ponds. In the first months (April, May and June) of 1972 the trophic nature of the ponds shifted from Chara sp. to the free living phytoplankton species. This shift in trophic nature reduced the microhabitat availability as well as changed the type of habitat. The organisms such as Odonata, Ephemeroptera and Coleoptera which lived within the Chara community gave way to substrate dwelling organisms such as the Annelid worms and the Dipterans. These organisms could survive by burrowing into the unprotected muds and fed upon the decaying Chara and other detritus. This type of benthic macrofauna population continued throughout 1972 and 1973.

A review of the benthic data indicated that throughout the study period the control test ponds responded in an identical manner as the stressed test ponds. Table 50

Table 50. BENTHOS STATISTICS
Paired t-Test - 95 percent Confidence Level

Parameter	Year	Test Ponds	df	$\overline{Y}$	$S_{\overline{Y}}$	$\overline{X}$	$S_{\overline{X}}$	F value	t_s	t_s^2	sig.
Diversity*	1971	1 versus 2	4	2.30	0.32	2.04	1.05	12.2	- 0.61	0.37	
	1972	1 versus 2	6	1.15	.51	1.24	.41	8.81	.48	.23	
	1973	1 versus 2	3	0.58	.41	0.61	.32	17.4	.14	.02	
	1971	3 versus 4	4	1.95	0.32	2.02	0.41	12.2	0.20	0.04	
	1972	3 versus 4	6	1.07	.52	1.20	.48	8.81	.70	.49	
	1973	3 versus 4	3	0.61	.46	.58	.44	17.4	.15	.02	
Richness S-1/lnN	1971	1 versus 2	4	2.19	0.60	1.89	0.73	12.2	-0.66	0.44	
	1972	1 versus 2	6	0.77	0.22	0.91	0.33	8.81	1.04	1.08	
	1973	1 versus 3	3	0.50	0.22	0.49	0.21	17.4	-0.14	0.02	
	1971	3 versus 4	4	1.64	0.37	1.92	0.16	12.2	2.53	6.40	
	1972	3 versus 4	6	0.64	0.35	0.74	0.44	8.81	0.81	0.66	
	1973	3 versus 4	3	0.26	0.19	0.29	0.26	17.4	0.33	0.11	
Richness $\frac{S}{\sqrt{N}}$	1972	1 versus 2	6	0.18	0.09	0.20	0.09	8.81	0.70	0.49	
	1973	1 versus 2	3	0.13	0.08	0.11	0.04	17.4	-0.57	0.32	
	1971	3 versus 4	4	1.95	0.32	2.02	0.41	12.2	0.20	0.04	
	1972	3 versus 4	6	0.26	0.12	0.21	0.12	8.81	-1.73	2.99	
	1973	3 versus 4	3	0.15	0.06	0.20	0.08	17.4	2.61	6.81	

*Diversity index used was Shannon Formula shows paired t statistical testing of species richness and diversity over the three year period for each pond pair (Pond 1 vs. Pond 2 and Pond 3 vs. Pond 4). A review of Table 50 indicates that over the study period no statistically significant differences were observed between Pond 1 when compared to Pond 2 or Pond 3 when compared to Pond 4.

Fish

Data from the fish flesh taste tests are given in Appendix C_{37}. This appendix presents percent wrong choices by the taste testers and the corresponding gallons of fuel burned per million gallons of diluent water at which the fish sample had been collected. Over the study period "wrong" choices were recorded on 62 percent of the samplings in the non-leaded test section (Pond 3) and on 74 percent of the fish samples taken from the leaded test section, Pond 3. The definition of a "wrong" choice by the taste panel has been discussed in the methodology section of this report. Further, data obtained on the fish flesh tainting on days with near-replicate fuel to diluent ratios indicate a divergent response by the taste panel to the taste of the fish, Table 51. A high degree of "wrong" choices are indicated on both leaded test pond samples while the variation in "wrong" choices range from 30 to 88 percent for fish from the non-leaded pond. At no time did a panel member indicate an off-flavor similar to a "petroleum-like taste". The greatest response to differences in the taste of the fish were directed at the texture of the fish tissue.

In reviewing the data generated on the sensory panel tasting of fish flesh in the northern lakes study the percent of inconsistent choices ("wrong" choices) forwarded by the

Table 51. WRONG CHOICES BY TASTE PANEL ON TWO SETS OF FISH SAMPLES

Test Pond	Gals of fuel burned/10^6 gals diluent water	Percent of wrong choices on taste identification
non-leaded (Pond 1)	4.0	30
leaded (Pond 3)	4.0	78
non-leaded (Pond 1)	4.2	88
leaded (Pond 3)	4.2	88

panel members indicate no correlation between outboard engine stressing and the tainting of fish muscle. In both test systems (leaded and non-leaded fuel test sections) less than 60 percent of the choices of all panel members identified a stressed fish as having a less desirable taste than a fish taken from the control sections. Little or no difference in the taste of fish from the ponds, whether control or stress section, is considered responsible for this wide range of choices. The taste differences noted due to texture are considered to be a result of normal variations between individual fish. These results are converse to the work of Surber(101) in which tainting of fish flesh was observed at 6.8 gallons of fuel burned per one million gallons of water. Surber, however, confined his test fish in live boxes(0.6 x 0.6 x 0.6 meters) at the surface of the test system, allowing for minimal movement. In this study the fish were allowed to roam for one year and some test fish were stocked into live boxes (2.1 x 2.1 x 1.1 meters) the subsequent year. In addition to the larger live boxes, fewer fish (25) were used per live box than in Surber's study. Also in this study the test fish were allowed to eat natural food whereas the fish in Surber's study were fed ordinary white bread. A review of Appendix C_{37} indicates no tainting or off-flavoring of fish flesh after 110 gallons of fuel burned per million gallons exposure level.

SECTION VI

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APPENDIX A1 - SURFACE AREA STRESS LEVELS

ASSUMPTIONS:

1. Water skiing requires - 40 bhp (brake horsepower)
2. Speed boating requires - 10 bhp
3. Fishing boat trolling requires - 5 bhp
4. Fishing boat requires - 0 bhp
5. One pound of fuel consumed per bhp - hr.
6. Six pounds of fuel per gallon of fuel
7. Peak boating activity - two days per week
8. Five days per week - one half peak boating activity
9. Eight month boating season

CALCULATIONS: Refer to Figures 2 and 3

I. 1000 hrs. to 1800 hrs. - 8 hour period

a. 150 boats water skiing
8 hrs. x 40 bhp/boat x 150 boats = 48,000 bhp - hr.

b. 150 boats cruising
8 hrs. x 10 bhp/boat x 150 boats = 12,000 bhp - hr.

c. 300 boats non-mobile = 0 bhp - hr.

Total_1 = 60,000 bhp - hr.

II. 0600 hrs. to 1000 hrs. and 1800 hrs. to 2000 hrs. - 6 hour period

a. 540 boats non-mobile = 0 bhp - hr.

b. 60 boats trolling
6 hrs. x 5 bhp/boat x 60 boats = 1,800 bhp - hr.

Total_2 = 1,800 bhp - hr.

III. $\text{Total}_1 + \text{Total}_2$ = 61,800 bhp - hr. per peak day

WEEKLY STRESS IN TERMS OF BHP - HOUR $= 2\,(T_1 + T_2) + 5 \left[\dfrac{T_1 + T_2}{2}\right]$

$= 2\,(61{,}800) + 5\,(30{,}900)$

$= 278{,}100$ bhp - hr.

WEEKLY STRESS IN TERMS OF BHP - HOUR PER ACRE

$$= \frac{\text{278,100 bhp - hr.}}{\text{surface area of Lake Geneva}}$$

$$= \frac{\text{278,100 bhp - hr.}}{\text{5100 acres}} = \frac{\text{55 bhp - hr.}}{\text{acre}}$$

WEEKLY STRESS IN TERMS OF GALLONS OF FUEL CONSUMED PER ACRE

$$= \frac{\text{55 bhp - hr.}}{\text{acre}} \times \frac{\text{1 lb fuel}}{\text{bhp - hr.}} \times \frac{\text{gallons fuel}}{\text{6 lbs. fuel}}$$

$$= \frac{\text{9 gallons fuel burned}}{\text{acre}}$$

$$= \frac{\text{84.15 liters of fuel burned}}{\text{hectare}}$$

APPENDIX A2 - SURFACE AREA STRESS LEVELS ON A YEARLY BASIS

YEARLY STRESS - assuming an 8 month boating period

Yearly Stress = 8 months/year x 4.1 weeks/month

x 55 bhp - hrs./acre - week

= 1804 bhp - hr./acre

= 1804 bhp - hr./acre x 1 lb. fuel/bhp - hr.

x 1 gallon fuel/6 lbs. fuel

= 300 gallons of fuel/acre (2806 liter/hectare)

APPENDIX A3 - VOLUME STRESS LEVELS ON A YEARLY BASIS

ASSUMPTIONS:

1. 8 month boating period
2. 12 foot (3.66 meters) water depth
3. Yearly surface area stress = 300 gallons of fuel burned per acre (Appendix A2)

CALCULATIONS:

$$\text{Yearly Volume Stress} = \text{Yearly Surface Area Stress} \div \text{Depth}$$

$$= 300 \frac{\text{gallons}}{\text{acre}} \times \frac{1}{12\text{ ft.}} = \frac{25\text{ gallons}}{\text{acre-ft.}}$$

$$= \frac{77\text{ gallons of fuel burned}}{\text{million gallons of water}}$$

APPENDIX B-1

ENGINES USED DURING TEST PERIOD

Manufacturer	Model No.	Engine Serial No.	Engine BHP	Model Year	Motor Type
Mercury	15002	3238485	50 hp	1972	drainless
Mercury	15002	3238629	50 hp	1972	drainless
Mercury	10402	3297340	4 hp	1972	drainless
Mercury	10402	3297276	4 hp	1972	drainless
Evinrude	18202	08215	18 hp	1972	drainless
Evinrude	18202	08246	18 hp	1972	drainless
Evinrude	2202	01036	2 hp	1972	drainless
Johnson	2R72	3530006	2 hp	1972	drainless
Chrysler	354HD	21581	35 hp	1972	drainless
Chrysler	354HD	21588	35 hp	1972	drainless
Chrysler	82HB	11132	8 hp	1972	drainless
Chrysler	82HB	11152	8 hp	1972	drainless

APPENDIX B$_2$ - STRESS LEVELS FOR TEST SECTIONS

A. Specifications
  1. 1/4 acre (0.1 hectare) test sections
  2. Average depth of test sections 6 feet (1.83 meters)

B. Volume of Test Section = 1.5 acre - feet
500,000 gallons

C. Yearly Calculated Optimum Stress Level = 77 gallons per 10^6 gallons
(Appendix A3)

Three Times Yearly Optimum Stress Level = 231 gallons per 10^6 gallons
or
231 liters per 10^6 liters

D. Daily Stress Level = 1 gallon per 10^6 gallons
(8 month period)

APPENDIX B3

Fuel Analysis: Indolene #30 (Leaded)

Test	ASTM Method	Specification Control Limit	Actual Test Results
API Gravity	D 287	58.0 - 61.0	59.0
Distillation:			
Initial Boiling Point (°F)	D 86	75 - 95	80
10% Evaporation (°F)	D 86	120 - 135	122
50% Evaporation (°F)	D 86	200 - 230	214
90% Evaporation (°F)	D 86	300 - 325	302
Maximum (°F)	D 86	≤ 415	378
Reid Vapor Pressure	D 323	8.7 - 9.2	9.2
Lead Content (g/gallon)	D 526	3.1 - 3.3	3.12
Sulfur Weight (%)	D1266	≤ 0.10	0.025
Olefin (%)	D1319	≤ 10	4.5
Aromatic (%)	D1319	≤ 35	27.0
Saturates (%)	D1319	Remainder	68.5
Octane, Research	D2699	≥ 103	104.4
Sensitivity	-	≤ 9.0	8.5
Hydrogen/Carbon Ratio	-	-	1.83

Batch No. SSS-Det.-7-1007

Data Source: American Oil Company

APPENDIX B4

Fuel Analysis: Indolene Clear (Non-Leaded)

Test	ASTM Method	Specification Control Limit	Actual Test Results
API Gravity	D 287	58.0 - 61.0	59.7
Distillation:			
Initial Boiling Point (°F)	D 86	75 - 95	92
10% Evaporation (°F)	D 86	120 - 135	131
50% Evaporation (°F)	D 86	200 - 230	220
90% Evaporation (°F)	D 86	300 - 325	310
Maximum (°F)	D 86	≤ 415	380
Reid Vapor Pressure	D 323	8.7 - 9.2	9.0
Gum (mg/100 ml)	D 381	≤ 4.0	2.8
Lead Content (g/gallon)	D 526	Nil	Nil
Sulfur Weight (%)	D1266	≤ 0.10	0.06
Olefin (%)	D1319	≤ 10	4.2
Aromatic (%)	D1319	≤ 35	30.1
Saturates (%)	D1319	Remainder	65.7
Octane, Research	D2699	96.0 - 98.5	97.4
Sensitivity	-	7.0 - 10.5	9.4
Hydrogen (%)	-	≤ 9.0	8.5
Hydrogen/Carbon Ratio	-	-	1.83

Batch No. SSS-Det.-7-1007

Data Source: American Oil Company

APPENDIX B_5

TRACE METAL IN BOTTOM SEDIMENTS
(mg/kg)

Sampling Date: November 1972

	STATION											
METAL	1A	1B	1C	2A	2B	2C	3A	3B	3C	4A	4B	4C
Chromium	30	42	68	32	28	38	30	33	45	37	39	33
Copper	6.0	10.3	31.7	9.5	6.9	9.4	11.2	16.3	29.4	12.7	9.7	12.6
Iron	1080	1110	1200	1120	1080	1110	1080	1180	1140	1110	1110	1050
Manganese	120	200	530	290	210	440	100	160	550	270	230	280
Nickel	93	116	204	71	70	107	70	114	174	137	122	123
Zinc	59	78	181	66	51	67	64	80	165	73	62	62

Sampling Date: July 1973

Chromium	25	16	15	14	27	19	16	18	20	21	17	14
Copper	14.3	18.9	16.7	8.9	70.0	24.3	10.5	17.1	46.2	61.9	18.4	32.0
Zinc	111	75	53	62	140	104	67	79	96	118	139	88

Correlation coefficient for lead and cadmium concentrations in the sediments of control Ponds 2 and 4 is (.682).

APPENDIX C_1
CHLORIDE
(mg/1)

DATE	TYPE OF SAMPLE	Pond 1	Pond 2	Pond 3	Pond 4
14 Sep 71	Composite	-	23	-	22
18 Sep 71	Composite	23	23	22	22
24 Sep 71	A	22	22	21	21
24 Sep 71	B	22	22	21	21
12 Oct 71	Composite	22	21	21	22
15 Oct 71	A	21	21	21	22
15 Oct 71	B	22	21	21	22
22 Oct 71	A	21	21	22	22
22 Oct 71	B	21	21	22	22
31 Oct 71	A	20	20	21	21
31 Oct 71	B	20	20	20	21
6 Nov 71	A	21	21	21	21
6 Nov 71	B	21	21	21	21
12 Nov 71	A	20	21	21	21
12 Nov 71	B	20	21	21	21
19 Nov 71	A	21	22	21	21
19 Nov 71	B	21	21	21	21
8 Jun 72	Composite	40	40	48	49
17 Jul 72	Composite	34	37	34	33
24 Jul 72	Composite	25	27	22	21
31 Jul 72	Composite	24	26	24	21
7 Aug 72	Composite	38	39	38	34
14 Aug 72	Composite	38	45	40	40
21 Aug 72	Composite	37	39	35	33
28 Aug 72	Composite	52	44	37	35
11 Sep 72	Composite	47	55	38	37
18 Sep 72	Composite	39	41	43	37
25 Sep 72	Composite	38	38	34	32
23 Oct 72	Composite	31	32	29	29
11 May 73	Composite	22	19	26	25
18 Jun 73	Composite	34	32	32	31
21 Aug 73	Composite	24	22	22	20

Composite refers to a) surface and middle samples at Station A
b) surface and middle samples at Station B
c) surface, middle, and depth samples at Station C
(reference Figure 5 this report)

A and B refer to composite of surface, middle, and depth samples taken at their respective stations (reference Figure 5 this report)

APPENDIX C_2

HARDNESS
(mg/l as $CaCO_3$)

DATE	TYPE OF SAMPLE	Pond 1	Pond 2	Pond 3	Pond 4
14 Sep 71	Composite	-	280	-	288
18 Sep 71	Composite	268	296	308	300
24 Sep 71	A	260	288	292	276
24 Sep 71	B	264	284	280	272
12 Oct 71	Composite	260	265	270	254
15 Oct 71	A	254	258	262	252
15 Oct 71	B	254	260	262	252
22 Oct 71	A	276	268	256	272
22 Oct 71	B	272	256	260	268
31 Oct 71	A	280	244	288	300
31 Oct 71	B	280	240	292	300
6 Nov 71	A	296	248	304	296
6 Nov 71	B	300	240	308	304
12 Nov 71	A	306	248	320	304
12 Nov 71	B	302	248	316	300
19 Nov 71	A	328	268	328	320
19 Nov 71	B	316	252	324	320
8 Jun 72	Composite	188	161	213	230
17 Jul 72	Composite	316	318	349	349
24 Jul 72	Composite	236	243	252	253
31 Jul 72	Composite	302	302	317	312
7 Aug 72	Composite	288	293	310	307
14 Aug 72	Composite	323	314	334	323
21 Aug 72	Composite	294	283	294	290
28 Aug 72	Composite	276	267	286	266
11 Sep 72	Composite	313	310	326	306
18 Sep 72	Composite	302	299	314	295
25 Sep 72	Composite	293	295	293	267
23 Oct 72	Composite	338	309	336	311
11 May 73	Composite	257	262	259	258
18 Jun 73	Composite	257	251	238	215
21 Aug 73	Composite	289	292	274	204

Composite refers to a) surface and middle samples at Station A
b) surface and middle samples at Station B
c) surface, middle, and depth samples at Station C
(reference Figure 5 this report)

A and B refer to composite of surface, middle and depth samples taken at their respective stations (reference Figure 5 this report)

APPENDIX C_3

Calcium
(mg/l)

DATE	TYPE OF SAMPLE	Pond 1	Pond 2	Pond 3	Pond 4
8 Jun 72	Composite	41	32	47	51
17 Jul 72	Composite	57	58	64	65
24 Jul 72	Composite	52	55	57	59
31 Jul 72	Composite	83	83	87	85
7 Aug 72	Composite	81	84	89	87
14 Aug 72	Composite	94	92	98	93
21 Aug 72	Composite	84	80	84	81
28 Aug 72	Composite	77	73	79	72
11 Sep 72	Composite	85	83	89	81
18 Sep 72	Composite	82	82	86	78
25 Sep 72	Composite	90	90	90	79
23 Oct 72	Composite	97	85	96	86
11 May 73	Composite	70	73	70	69
18 Jun 73	Composite	68	65	58	49
21 Aug 73	Composite	78	78	70	43

Composite refers to a) surface and middle samples at Station A
b) surface and middle samples at Station B
c) surface, middle, and depth samples at Station C
(reference Figure 5 this report)

APPENDIX C_4

MAGNESIUM
(mg/1)

DATE	TYPE OF SAMPLE	Pond 1	Pond 2	Pond 3	Pond 4
8 Jun 72	Composite	21	20	23	25
17 Jul 72	Composite	42	42	46	46
24 Jul 72	Composite	26	26	27	26
31 Jul 72	Composite	23	23	24	24
7 Aug 72	Composite	21	21	22	22
14 Aug 72	Composite	22	21	22	22
21 Aug 72	Composite	21	20	21	21
28 Aug 72	Composite	21	20	21	21
11 Sep 72	Composite	25	25	26	25
18 Sep 72	Composite	24	23	24	24
25 Sep 72	Composite	17	17	17	17
23 Oct 72	Composite	23	24	24	23
11 May 73	Composite	20	19	20	21
18 Jun 73	Composite	22	22	22	23
21 Aug 73	Composite	23	24	24	24

Composite refers to a) surface and middle samples at Station A
b) surface and middle samples at Station B
c) surface, middle, and depth samples at Station C
(reference Figure 5 this report)

APPENDIX C_5

ALKALINITY

(mg/l as $CaCO_3$)

DATE	TYPE OF SAMPLE	Pond 1	Pond 2	Pond 3	Pond 4
14 Sep 71	Composite	-	155	-	164
18 Sep 71	Composite	140	168	176	172
24 Sep 71	A	143	160	152	154
24 Sep 71	B	140	158	157	153
12 Oct 71	Composite	154	154	170	182
15 Oct 71	A	143	153	163	164
15 Oct 71	B	144	152	162	159
22 Oct 71	A	157	138	140	153
22 Oct 71	B	156	138	140	140
31 Oct 71	A	158	124	167	171
31 Oct 71	B	157	124	167	171
6 Nov 71	A	164	126	172	173
6 Nov 71	B	169	127	177	171
12 Nov 71	A	171	126	188	181
12 Nov 71	B	178	129	184	179
19 Nov 71	A	193	132	201	204
19 Nov 71	B	191	135	198	200
8 Jun 72	Composite	84	56	89	90
17 Jul 72	Composite	152	155	162	165
24 Jul 72	Composite	179	192	195	184
31 Jul 72	Composite	179	192	195	184
7 Aug 72	Composite	190	196	201	200
14 Aug 72	Composite	200	205	212	205
21 Aug 72	Composite	186	204	186	177
28 Aug 72	Composite	189	185	179	175
11 Sep 72	Composite	197	195	192	181
18 Sep 72	Composite	194	208	190	176
25 Sep 72	Composite	197	201	173	145
2 Oct 72	Composite	204	205	190	162
9 Oct 72	Composite	220	212	201	186
16 Oct 72	Composite	222	219	205	174
23 Oct 72	Composite	223	217	199	192
30 Oct 72	Composite	229	220	211	200
11 May 73	Composite	144	155	150	157
29 May 73	Composite	152	160	149	132
18 Jun 73	Composite	188	186	169	159
2 Jul 73	Composite	165	167	145	130
23 Jul 73	Composite	178	190	158	125
21 Aug 73	Composite	171	201	168	98

Composite refers to a) surface and middle samples at Station A
b) surface and middle samples at Station B
c) surface, middle, and dpeth samples at Station C
(reference Figure 5 this report)

A and B refer to composite of surface, middle, and dpeth samples taken at their respective stations (reference Figure 5 this report)

APPENDIX C_6

SULFATE
(mg/1)

DATE	TYPE OF SAMPLE	Pond 1	Pond 2	Pond 3	Pond 4
11 May 73	Composite	110	95	100	110
18 Jun 73	Composite	86	74	85	85
21 Aug 73	Composite	106	95	105	106

Composite refers to a) surface and middle samples at Station A
b) surface and middle samples at Station B
c) surface, middle, and depth samples at Station C
(reference Figure 5 this report)

APPENDIX C_7

BROMIDE
(mg/l)

DATE	TYPE OF SAMPLE	Pond 1	Pond 2	Pond 3	Pond 4
12 Oct 71	Composite	0.80	0.75	0.85	0.75
15 Oct 71	A	0.75	0.80	0.85	0.85
15 Oct 71	B	0.90	0.65	0.80	0.80
22 Oct 71	A	0.70	0.78	1.00	0.90
22 Oct 71	B	0.85	0.92	0.95	0.90
31 Oct 71	A	0.45	0.52	0.52	0.37
31 Oct 71	B	0.47	0.61	0.36	0.62
6 Nov 71	A	0.43	0.50	0.51	0.55
6 Nov 71	B	0.45	0.55	0.45	0.60
12 Nov 71	A	0.19	0.30	0.30	0.52
12 Nov 71	B	0.25	0.45	0.50	0.61
19 Nov 71	A	0.23	0.32	0.30	0.45
19 Nov 71	B	0.23	0.35	0.37	0.50
8 Jun 72	Composite	<0.10	0.81	<0.10	<0.10
17 Jul 72	Composite	0.30	0.28	0.27	0.29
24 Jul 72	Composite	0.12	0.12	0.13	0.12
31 Jul 72	Composite	0.12	0.14	0.15	0.12
7 Aug 72	Composite	0.31	0.31	0.31	0.32
14 Aug 72	Composite	0.24	0.34	0.22	0.29
21 Aug 72	Composite	0.26	0.28	0.25	0.23
28 Aug 72	Composite	0.27	0.25	0.29	0.27
11 Sep 72	Composite	0.31	0.24	0.25	0.26
18 Sep 72	Composite	0.23	0.33	0.32	0.28
25 Sep 72	Composite	0.32	0.41	0.40	0.37
23 Oct 72	Composite	0.27	0.28	0.25	0.23
11 May 73	Composite	0.18	0.20	0.19	0.20
18 Jun 73	Composite	0.22	0.30	0.27	0.28
21 Aug 73	Composite	0.23	0.25	0.23	0.23

Composite refers to a) surface and middle samples at Station A
b) surface and middle samples at Station B
c) surface, middle, and depth samples at Station C
(reference Figure 5 this report)

A and B refer to composite of surface, middle and depth samples taken at their respective stations (reference Figure 5 this report)

APPENDIX C_8

CONDUCTIVITY
(micro mhos)

DATE	SAMPLE STATION*	Pond 1	Pond 2	Pond 3	Pond 4
2 Oct 72	A-S	580	580	550	510
2 Oct 72	A-M	580	550	560	510
2 Oct 72	B-S	580	550	550	510
2 Oct 72	B-M	580	550	580	510
2 Oct 72	C-S	580	550	590	510
2 Oct 72	C-M	580	550	590	510
9 Oct 72	A-S	500	490	490	440
9 Oct 72	A-M	500	490	490	440
9 Oct 72	B-S	500	490	490	440
9 Oct 72	B-M	500	490	490	440
9 Oct 72	C-S	500	490	490	440
9 Oct 72	C-M	500	490	490	440
16 Oct 72	A-S	455	450	435	420
16 Oct 72	A-M	460	450	430	420
16 Oct 72	B-S	465	455	450	425
16 Oct 72	B-M	455	450	440	425
16 Oct 72	C-S	470	460	455	425
16 Oct 72	C-M	455	455	450	420
23 Oct 72	A-S	445	440	425	400
23 Oct 72	A-M	450	440	420	400
23 Oct 72	B-S	445	445	425	405
23 Oct 72	B-M	445	440	425	405
23 Oct 72	C-S	450	440	425	405
23 Oct 72	C-M	445	445	430	410
23 Oct 72	C-D	445	440	430	410
30 Oct 72	A-S	465	450	435	405
30 Oct 72	A-M	465	450	435	410
30 Oct 72	B-S	460	450	435	400
30 Oct 72	B-M	470	450	430	410
30 Oct 72	C-S	465	445	435	405
30 Oct 72	C-M	470	440	430	410
30 Oct 72	C-D	465	450	430	410

* refer to Figure 5 - this report

APPENDIX C_9

TEMPERATURE

(^{o}C)

DATE	SAMPLE STATION*	Pond 1	Pond 2	Pond 3	Pond 4
13 Dec 71	B-S	2.8	2.8	2.8	2.8
13 Dec 71	B-M	2.8	2.8	2.8	2.8
13 Dec 71	B-D	2.8	2.8	2.8	2.8
24 Jul 72	A-S	26.0	26.0	26.0	26.0
24 Jul 72	A-M	25.5	25.5	26.0	26.0
24 Jul 72	B-S	26.0	26.0	26.0	26.0
24 Jul 72	B-M	25.5	25.5	25.5	26.0
24 Jul 72	C-S	26.0	25.8	26.0	26.0
24 Jul 72	C-M	25.5	25.2	25.5	26.0
24 Jul 72	C-D	25.5	25.0	25.0	25.5
31 Jul 72	A-S	24.5	24.5	24.0	24.0
31 Jul 72	A-M	24.0	24.0	23.5	23.5
31 Jul 72	B-S	24.5	24.0	24.0	24.0
31 Jul 72	B-M	24.0	24.0	23.5	23.5
31 Jul 72	C-S	24.5	24.0	24.0	24.0
31 Jul 72	C-M	24.5	24.0	23.5	23.5
31 Jul 72	C-D	24.0	24.0	23.0	23.0
15 Aug 72	A-S	21.0	22.0	22.0	21.0
15 Aug 72	A-M	21.0	22.0	22.0	21.0
15 Aug 72	B-S	21.0	22.0	22.0	21.0
15 Aug 72	B-M	21.0	22.0	22.0	20.0
15 Aug 72	C-S	22.0	22.0	22.0	21.0
15 Aug 72	C-M	22.0	21.0	21.0	20.0
15 Aug 72	C-D	20.0	20.0	20.0	19.0
2 Oct 72	A-S	17.0	17.5	17.0	17.0
2 Oct 72	A-M	16.5	17.0	16.5	16.0
2 Oct 72	B-S	17.0	17.5	17.0	17.0
2 Oct 72	B-M	16.5	17.0	16.0	16.0
2 Oct 72	C-S	17.0	17.5	17.0	17.0
2 Oct 72	C-M	17.0	17.0	16.5	16.0
2 Oct 72	C-D	16.5	16.0	15.0	15.0
9 Oct 72	A-S	11.5	12.0	11.0	11.5
9 Oct 72	A-M	11.5	12.0	11.5	11.5
9 Oct 72	B-S	12.0	11.5	11.0	11.5
9 Oct 72	B-M	12.0	12.0	11.5	11.5
9 Oct 72	C-S	12.0	11.5	11.5	11.5
9 Oct 72	C-M	12.0	12.0	11.0	11.5
16 Oct 72	A-S	8.0	8.0	8.5	7.0
16 Oct 72	A-M	8.0	8.0	8.0	7.0
16 Oct 72	B-S	8.5	8.0	8.0	7.5
16 Oct 72	B-M	8.0	7.5	7.5	7.5
16 Oct 72	C-S	8.5	9.0	8.0	8.0
16 Oct 72	C-M	7.5	8.0	7.5	8.0
23 Oct 72	A-S	8.5	8.0	8.0	7.5
23 Oct 72	A-M	8.5	7.5	8.0	7.0
23 Oct 72	B-S	9.0	8.0	8.0	7.5
23 Oct 72	B-M	8.0	7.5	7.5	7.5
23 Oct 72	C-S	9.0	8.0	8.0	7.0
23 Oct 72	C-M	8.0	8.0	8.0	7.5
23 Oct 72	C-D	8.0	8.0	10.0	7.5

APPENDIX C_9

TEMPERATURE

(°C)

Continued

DATE	SAMPLE STATION*	Pond 1	Pond 2	Pond 3	Pond 4
30 Oct 72	A-S	8.0	7.0	7.5	7.0
30 Oct 72	A-M	7.5	7.0	7.5	7.0
30 Oct 72	B-S	8.0	7.0	8.0	7.0
30 Oct 72	B-M	7.0	7.0	7.5	7.0
30 Oct 72	C-S	8.0	7.0	8.0	7.0
30 Oct 72	C-M	7.0	7.0	7.5	7.0
30 Oct 72	C-D	7.5	6.5	7.5	6.5
3 Nov 72	A-S	8.0	7.5	9.0	8.0
3 Nov 72	A-M	7.5	7.0	8.0	8.0
3 Nov 72	B-S	8.0	7.5	8.5	8.0
3 Nov 72	B-M	7.5	7.5	8.0	7.5
3 Nov 72	C-S	8.0	8.0	8.0	8.0
3 Nov 72	C-M	7.5	7.5	7.5	8.0
3 Nov 72	C-D	7.5	7.5	7.5	8.0
27 Nov 72	A-S	2.0	3.0	4.0	2.0
27 Nov 72	A-M	4.0	4.0	4.0	4.0
27 Nov 72	B-S	3.0	3.0	2.0	2.0
27 Nov 72	B-M	4.0	4.0	4.0	3.5
27 Nov 72	C-S	4.0	3.0	3.0	2.5
27 Nov 72	C-M	4.0	4.0	4.0	3.5
27 Nov 72	C-D	4.0	4.0	4.0	3.5

* refer to Figure 5 - this report

APPENDIX C_{10}

TOTAL PHOSPHORUS
(mg/l)

DATE	TYPE OF SAMPLE	Pond 1	Pond 2	Pond 3	Pond 4
14 Sep 71	Composite	-	-	-	<0.030
18 Sep 71	Composite	<0.030	<0.030	<0.030	<0.030
24 Sep 71	A	<0.030	<0.030	<0.030	<0.030
24 Sep 71	B	<0.030	<0.030	<0.030	<0.030
12 Oct 71	Composite	<0.030	<0.030	<0.030	<0.030
15 Oct 71	A	<0.030	<0.030	<0.030	<0.030
15 Oct 71	B	<0.030	<0.030	<0.030	<0.030
22 Oct 71	A	<0.030	<0.030	<0.030	<0.030
22 Oct 71	B	<0.030	<0.030	<0.030	<0.030
31 Oct 71	A	<0.030	<0.030	<0.030	<0.030
31 Oct 71	B	<0.030	<0.030	<0.030	<0.030
6 Nov 71	A	<0.030	<0.030	<0.030	<0.030
6 Nov 71	B	<0.030	<0.030	<0.030	<0.030
12 Nov 71	A	<0.030	<0.030	<0.030	<0.030
12 Nov 71	B	<0.030	<0.030	<0.030	<0.030
8 Jun 72	Composite	<0.005	<0.005	<0.005	<0.005
17 Jul 72	Composite	<0.005	<0.005	<0.005	<0.005
24 Jul 72	Composite	<0.005	<0.005	<0.005	<0.005
31 Jul 72	Composite	<0.005	<0.005	<0.005	<0.005
7 Aug 72	Composite	0.141	0.133	0.251	0.208
14 Aug 72	Composite	<0.005	<0.005	<0.005	<0.005
21 Aug 72	Composite	<0.005	<0.005	<0.005	<0.005
28 Aug 72	Composite	<0.005	<0.005	<0.005	<0.005
11 Sep 72	Composite	0.025	0.033	0.033	0.030
18 Sep 72	Composite	<0.005	<0.005	<0.005	<0.005
25 Sep 72	Composite	<0.005	<0.005	<0.005	<0.005
23 Oct 72	Composite	0.060	0.077	0.075	0.085
11 May 73	Composite	0.021	0.021	0.023	0.034
18 Jun 73	Composite	0.050	0.039	0.075	0.085
21 Aug 73	Composite	0.020	0.016	0.041	0.073

Composite refers to a) surface and middle samples at Station A
b) surface and middle samples at Station B
c) surface, middle, and depth samples at Station C
(reference Figure 5 this report)

A and B refer to composite of surface, middle, and depth samples taken at their respective stations (reference Figure 5 this report)

APPENDIX C_{11}

ORTHO PHOSPHATE
(mg/l as P)

DATE	TYPE OF SAMPLE	Pond 1	Pond 2	Pond 3	Pond 4
14 Sep 71	Composite	-	-	-	<0.030
18 Sep 71	Composite	<0.030	<0.030	<0.030	<0.030
24 Sep 71	A	<0.030	<0.030	<0.030	<0.030
24 Sep 71	B	<0.030	<0.030	<0.030	<0.030
12 Oct 71	Composite	<0.030	<0.030	<0.030	<0.030
15 Oct 71	A	<0.030	<0.030	<0.030	<0.030
15 Oct 71	B	<0.030	<0.030	<0.030	<0.030
22 Oct 71	A	<0.030	<0.030	<0.030	<0.030
22 Oct 71	B	<0.030	<0.030	<0.030	<0.030
31 Oct 71	A	<0.030	<0.030	<0.030	<0.030
31 Oct 71	B	<0.030	<0.030	<0.030	<0.030
6 Nov 71	A	<0.030	<0.030	<0.030	<0.030
6 Nov 71	B	<0.030	<0.030	<0.030	<0.030
12 Nov 71	A	<0.030	<0.030	<0.030	<0.030
12 Nov 71	B	<0.030	<0.030	<0.030	<0.030
8 Jun 72	Composite	<0.005	<0.005	<0.005	<0.005
17 Jul 72	Composite	<0.005	<0.005	<0.005	<0.005
24 Jul 72	Composite	<0.005	<0.005	<0.005	<0.005
31 Jul 72	Composite	<0.005	<0.005	<0.005	<0.005
7 Aug 72	Composite	<0.005	<0.005	<0.005	<0.005
14 Aug 72	Composite	<0.005	<0.005	<0.005	<0.005
21 Aug 72	Composite	<0.005	<0.005	<0.005	<0.005
28 Aug 72	Composite	<0.005	<0.005	<0.005	<0.005
11 Sep 72	Composite	<0.005	<0.005	<0.005	<0.005
18 Sep 72	Composite	<0.005	<0.005	<0.005	<0.005
25 Sep 72	Composite	<0.005	<0.005	<0.005	<0.005
23 Oct 72	Composite	<0.005	<0.005	<0.005	<0.005
11 May 73	Composite	<0.005	<0.005	<0.005	<0.005
18 Jun 73	Composite	<0.005	<0.005	<0.005	<0.005
21 Aug 73	Composite	0.011	0.012	0.010	0.006

Composite refers to a) surface and middle samples at Station A
b) surface and middle samples at Station B
c) surface, middle, and depth samples at Station C
(reference Figure 5 this report)

A and B refer to composite of surface, middle, and depth samples taken at their respective stations (reference Figure 5 this report)

APPENDIX C_{12}

ORGANIC NITROGEN
(mg/1)

Date	Type of Sample	Pond 1	Pond 2	Pond 3	Pond 4
14 Sep 71	Composite	-	<0.10	-	<0.10
18 Sep 71	Composite	<0.10	<0.10	<0.10	<0.10
24 Sep 71	A	0.20	0.20	<0.10	<0.10
24 Sep 71	B	0.25	0.20	<0.10	0.10
12 Oct 71	Composite	<0.10	<0.10	<0.10	<0.10
15 Oct 71	A	<0.10	<0.10	<0.10	<0.10
15 Oct 71	B	<0.10	<0.10	<0.10	<0.10
22 Oct 71	A	<0.10	<0.10	<0.10	<0.10
22 Oct 71	B	<0.10	<0.10	<0.10	<0.10
31 Oct 71	A	0.11	0.11	0.22	0.45
31 Oct 71	B	<0.10	<0.10	<0.10	0.33
6 Nov 71	A	0.11	<0.10	0.22	0.17
6 Nov 71	B	<0.10	<0.10	0.17	0.11
12 Nov 71	A	0.22	<0.17	<0.10	0.11
12 Nov 71	B	0.12	<0.17	<0.10	<0.10
8 Jun 72	Composite	0.54	0.54	0.58	0.71
17 Jul 72	Composite	0.50	0.54	0.37	0.41
24 Jul 72	Composite	0.41	0.56	0.73	0.60
31 Jul 72	Composite	<0.01	0.05	0.12	0.09
7 Aug 72	Composite	1.27	0.77	1.98	1.47
14 Aug 72	Composite	0.49	0.57	0.64	0.89
21 Aug 72	Composite	0.59	0.71	0.79	0.64
28 Aug 72	Composite	0.98	1.07	1.10	0.99
11 Sep 72	Composite	0.80	1.86	0.72	0.51
18 Sep 72	Composite	1.07	0.89	0.95	1.10
25 Sep 72	Composite	1.19	2.13	1.30	1.57
23 Oct 72	Composite	0.76	1.80	0.76	1.07
11 May 73	Composite	0.26	0.18	0.34	0.12
18 Jun 73	Composite	0.96	2.13	0.41	0.07
21 Aug 73	Composite	1.37	1.14	1.97	0.37

Composite refers to a) surface and middle samples at station A
b) surface and middle samples at station B
c) surface, middle, and depth samples at station C
(reference Figure 5 this report)

A and B refer to composite of surface, middle, and depth samples taken at their respective stations (reference Figure 5 this report)

APPENDIX C_{13}
NITRATE NITROGEN
(mg/l)

DATE	TYPE OF SAMPLE	Pond 1	Pond 2	Pond 3	Pond 4
12 Oct 71	Composite	<0.10	<0.10	<0.10	<0.10
15 Oct 71	A	<0.10	<0.10	<0.10	<0.10
15 Oct 71	B	<0.10	<0.10	<0.10	<0.10
22 Oct 71	A	<0.10	<0.10	<0.10	<0.10
22 Oct 71	B	<0.10	<0.10	<0.10	<0.10
31 Oct 71	A	<0.10	<0.10	<0.10	0.10
31 Oct 71	B	<0.10	<0.10	<0.10	<0.10
6 Nov 71	A	<0.10	0.11	<0.10	<0.10
6 Nov 71	B	0.15	<0.10	<0.10	<0.10
12 Nov 71	A	0.10	<0.10	<0.10	<0.10
12 Nov 71	B	<0.10	<0.10	<0.10	<0.10
8 Jun 72	Composite	0.03	0.01	0.03	0.03
17 Jul 72	Composite	0.02	0.02	<0.01	<0.01
24 Jul 72	Composite	0.05	0.08	0.07	0.06
31 Jul 72	Composite	<0.03	<0.03	<0.03	<0.03
7 Aug 72	Composite	0.32	0.30	0.60	0.36
14 Aug 72	Composite	0.19	0.19	0.16	0.15
21 Aug 72	Composite	0.40	0.35	0.38	0.32
28 Aug 72	Composite	0.27	0.28	0.28	0.29
11 Sep 72	Composite	0.28	0.28	0.23	0.14
18 Sep 72	Composite	0.45	0.36	0.31	0.33
25 Sep 72	Composite	0.17	0.25	0.20	0.19
23 Oct 72	Composite	0.21	0.25	0.28	0.25
11 May 73	Composite	0.54	0.40	0.50	0.51
18 Jun 73	Composite	0.46	0.48	0.58	0.95
21 Aug 73	Composite	0.56	0.50	0.82	0.58

Composite refers to a) surface and middle samples at Station A
b) surface and middle samples at Station B
c) surface, middle, and depth samples at Station C
(reference Figure 5 this report)

A and B refer to composite of surface, middle, and depth samples taken at their respective stations (reference Figure 5 this report)

APPENDIX C_{14}

AMMONIA NITROGEN
(mg/1)

DATE	TYPE OF SAMPLE	Pond 1	Pond 2	Pond 3	Pond 4
14 Sep 71	Composite	-	<0.05	-	<0.05
18 Sep 71	Composite	<0.05	<0.05	<0.05	<0.05
24 Sep 71	A	<0.05	<0.05	<0.05	<0.05
24 Sep 71	B	<0.05	<0.05	<0.05	<0.05
12 Oct 71	Composite	<0.05	<0.05	<0.05	<0.05
15 Oct 71	A	<0.05	<0.05	<0.05	<0.05
15 Oct 71	B	<0.05	<0.05	<0.05	<0.05
22 Oct 71	A	<0.05	<0.05	<0.05	<0.05
22 Oct 71	B	<0.05	<0.05	<0.05	<0.05
31 Oct 71	A	<0.05	<0.05	<0.05	<0.05
31 Oct 71	B	<0.05	<0.05	<0.05	<0.05
6 Nov 71	A	<0.05	<0.05	<0.05	<0.05
6 Nov 71	B	<0.05	<0.05	<0.05	<0.05
12 Nov 71	A	<0.05	<0.05	<0.05	<0.05
12 Nov 71	B	<0.05	<0.05	<0.05	<0.05
19 Nov 71	A	<0.05	<0.05	<0.05	<0.05
19 Nov 71	B	<0.05	<0.05	<0.05	<0.05
8 Jun 72	Composite	<0.05	<0.05	<0.05	<0.05
17 Jul 72	Composite	<0.05	<0.05	<0.05	<0.05
24 Jul 72	Composite	0.022	0.011	0.021	0.010
31 Jul 72	Composite	0.048	0.023	0.013	0.011
7 Aug 72	Composite	0.012	0.009	0.006	0.013
14 Aug 72	Composite	0.032	0.034	0.012	0.016
21 Aug 72	Composite	0.039	0.040	0.031	0.026
28 Aug 72	Composite	0.015	0.016	0.009	0.012
11 Sep 72	Composite	0.020	0.020	0.026	0.010
18 Sep 72	Composite	0.033	0.027	0.022	0.021
25 Sep 72	Composite	0.019	0.015	0.018	0.018
23 Oct 72	Composite	0.049	0.059	0.020	0.063
11 May 73	Composite	0.048	0.039	0.047	0.053
18 Jun 73	Composite	0.036	0.113	0.017	0.075
21 Aug 73	Composite	0.073	0.081	0.042	0.057

Composite refers to a) surface and middle samples at Station A
b) surface and middle samples at Station B
c) surface, middle, and depth samples at Station C
(reference Figure 5 this report)

A and B refer to composite of surface, middle, and depth samples taken at their respective stations (reference Figure 5 this report)

APPENDIX C_{15}

NITRITE NITROGEN
(mg/1)

DATE	TYPE OF SAMPLE	Pond 1	Pond 2	Pond 3	Pond 4
14 Sep 71	Composite	-	<.005	-	<.005
18 Sep 71	Composite	<.005	<.005	<.005	<.005
24 Sep 71	A	<.005	<.005	<.005	<.005
24 Sep 71	B	<.005	<.005	<.005	<.005
12 Oct 71	Composite	<.005	<.005	<.005	<.005
15 Oct 71	A	<.005	<.005	<.005	<.005
15 Oct 71	B	<.005	<.005	<.005	<.005
22 Oct 71	A	<.005	<.005	<.005	<.005
22 Oct 71	B	<.005	<.005	<.005	<.005
31 Oct 71	A	.006	<.005	.008	.005
31 Oct 71	B	.006	<.005	.008	.005
6 Nov 71	A	<.005	<.005	<.005	<.005
6 Nov 71	B	<.005	<.005	<.005	<.005
12 Nov 71	A	.005	.008	.006	.005
12 Nov 71	B	.005	.008	.006	.005
19 Nov 71	A	<.005	<.005	<.005	<.005
19 Nov 71	B	<.005	<.005	<.005	<.005
8 Jun 72	Composite	<.001	<.001	<.001	<.001
17 Jul 72	Composite	<.001	<.001	<.001	<.001
24 Jul 72	Composite	<.001	<.001	<.001	<.001
31 Jul 72	Composite	<.001	<.001	<.001	<.001
7 Aug 72	Composite	<.001	<.001	<.001	<.001
14 Aug 72	Composite	<.001	<.001	<.001	<.001
21 Aug 72	Composite	<.001	<.001	<.001	<.001
28 Aug 72	Composite	<.001	<.001	<.001	<.001
11 Sep 72	Composite	<.001	<.001	<.001	<.001
18 Sep 72	Composite	<.001	<.001	<.001	<.001
25 Sep 72	Composite	<.001	<.001	<.001	<.001
23 Oct 72	Composite	<.001	<.001	<.001	<.001
11 May 73	Composite	<.001	<.001	.005	.005
18 Jun 73	Composite	<.001	.002	<.001	<.001
21 Aug 73	Composite	.002	.005	.001	.003

Composite refers to a) surface and middle samples at Station A
b) surface and middle samples at Station B
c) surface, middle, and depth samples at Station C
(reference Figure 5 this report)

A and B refer to composite of surface, middle, and depth samples taken at their respective stations (reference Figure 5 this report)

APPENDIX C_{16}

pH

Date	Type of Sample	Pond 1	Pond 2	Pond 3	Pond 4
14 Sep 71	Composite	-	7.6	-	7.7
18 Sep 71	Composite	8.1	8.0	8.1	8.0
24 Sep 71	A	8.0	7.9	7.9	8.0
24 Sep 71	B	8.1	7.8	7.7	8.1
12 Oct 71	Composite	7.7	8.0	7.7	8.1
15 Oct 71	A	7.7	8.1	7.9	8.2
15 Oct 71	B	8.1	8.1	7.9	8.1
22 Oct 71	A	8.0	8.0	8.0	8.2
22 Oct 71	B	8.1	8.0	7.9	8.4
31 Oct 71	A	7.6	8.1	7.6	8.2
31 Oct 71	B	7.6	8.1	7.6	8.1
6 Nov 71	A	8.2	8.3	8.3	8.3
6 Nov 71	B	8.2	8.3	8.2	8.3
12 Nov 71	A	7.6	8.2	7.7	8.2
12 Nov 71	B	7.9	8.2	7.8	8.2
19 Nov 71	A	7.9	8.0	7.8	7.8
19 Nov 71	B	7.9	8.0	7.9	7.9
8 Jun 72	Composite	7.00	7.00	7,15	7,30
17 Jul 72	Composite	7.93	7.91	8.10	8.16
24 Jul 72	Composite	7.95	7.92	7.88	8.10
31 Jul 72	Composite	7.92	7.85	7.93	7.95
7 Aug 72	Composite	8.06	8,00	7.99	7.99
14 Aug 72	Composite	8.00	8.03	8.06	8.02
21 Aug 72	Composite	8.14	8.38	8.30	8.35
28 Aug 72	Composite	8.39	8.30	7.76	8.33
11 Sep 72	Composite	8.36	8.37	8.33	8.36
18 Sep 72	Composite	8.12	8.24	8.21	8.29
25 Sep 72	Composite	8.29	8.39	8.37	8.41
2 Oct 72	Composite	8.28	8.32	8.38	8.41
9 Oct 72	Composite	8.32	8.08	8.36	8.36
16 Oct 72	Composite	8.18	8.25	8.37	8.44
23 Oct 72	Composite	8.39	8.32	8.45	8.45
30 Oct 72	Composite	8.20	8.16	8.28	8.29
11 May 73	Composite	8.42	8.33	8.50	8.55
29 May 73	Composite	8.09	8.28	8.38	8.58
18 Jun 73	Composite	8.07	8.01	8.23	8.37
2 Jul 73	Composite	7.72	8.36	8.36	8,32
23 Jul 73	Composite	8.14	8.15	8.07	8.46
21 Aug 73	Composite	8.24	8.21	8.28	8.73

Composite refers to a) surface and middle samples at station A
b) surface and middle samples at station B
c) surface, middle, and depth samples at station C
(reference Figure 5 this report)

A and B refer to composite of surface, middle, and depth samples taken at their respective stations (reference Figure 5 this report)

APPENDIX C_{17}

DISSOLVED OXYGEN
(mg/1)

DATE	SAMPLE STATION *	Pond 1	Pond 2	Pond 3	Pond 4
13 Dec 71	B-S	14.5	16.0	16.2	16.0
13 Dec 71	B-M	15.0	16.1	16.2	16.0
13 Dec 71	B-D	15.2	16.0	16.2	16.0
26 Jul 72	A-S	3.5	4.6	6.3	7.2
24 Jul 72	A-M	3.0	3.5	5.4	6.6
24 Jul 72	B-S	3.3	4.1	6.5	7.8
24 Jul 72	B-M	3.0	4.4	4.6	6.4
24 Jul 72	C-S	3.4	3.5	6.8	8.4
24 Jul 72	C-M	3.1	3.8	4.7	7.0
24 Jul 72	C-D	2.9	3.3	3.9	8.2
31 Jul 72	A-S	5.2	5.2	6.5	6.6
31 Jul 72	A-M	5.0	4.5	5.1	5.2
31 Jul 72	B-S	5.2	5.4	6.3	6.6
31 Jul 72	B-M	4.8	3.7	4.7	4.9
31 Jul 72	C-S	5.4	5.4	6.2	6.6
31 Jul 72	C-M	5.0	5.1	4.7	5.5
31 Jul 72	C-D	4.5	3.7	3.0	3.8
14 Aug 72	A-S	8.7	8.4	8.4	8.8
14 Aug 72	A-M	8.5	8.2	8.2	8.7
14 Aug 72	B-S	8.6	8.0	8.0	8.8
14 Aug 72	B-M	7.0	7.0	7.0	6.5
14 Aug 72	C-S	8.7	7.8	7.8	8.6
14 Aug 72	C-M	7.2	4.0	4.0	5.8
14 Aug 72	C-D	2.8	2.4	2.4	2.8
2 Oct 72	A-S	7.2	6.2	6.2	6.1
2 Oct 72	A-M	6.5	4.9	6.2	5.8
2 Oct 72	B-S	8.2	6.5	6.8	6.2
2 Oct 72	B-M	7.1	5.9	6.5	6.1
2 Oct 72	C-S	8.3	5.8	6.0	6.6
2 Oct 72	C-M	8.1	4.9	5.9	6.2
2 Oct 72	C-D	7.2	4.2	5.4	6.2
3 Nov 72	A-S	10.2	9.6	10.4	10.4
3 Nov 72	A-M	9.8	9.4	10.0	10.0
3 Nov 72	B-S	10.4	9.6	10.6	10.1
3 Nov 72	B-M	10.2	9.5	10.0	9.8
3 Nov 72	C-S	10.2	10.0	10.4	10.1
3 Nov 72	C-M	10.2	9.5	10.3	10.0
3 Nov 72	C-D	10.0	8.2	9.8	10.0
27 Nov 72	A-S	12.6	10.4	11.6	11.6
27 Nov 72	A-M	11.4	10.4	11.6	11.6
27 Nov 72	B-S	11.8	11.2	11.6	11.8
27 Nov 72	B-M	11.2	11.0	11.4	11.8
27 Nov 72	C-S	11.0	10.6	11.4	12.0
27 Nov 72	C-M	11.0	10.6	11.2	11.8
27 Nov 72	C-D	11.0	10.4	11.0	11.8

* refer to Figure 5 this report

APPENDIX C_{18}

TURBIDITY
(Jackson Units)

Date	Type of Sample	Pond 1	Pond 2	Pond 3	Pond 4
16 Oct 72	Composite	6.7	9.5	17.0	18.0
20 Nov 72	Composite	8.1	8.15	9.0	10.0

VOLATILE SUSPENDED SOLIDS
(mg/1)

Date	Type of Sample	Pond 1	Pond 2	Pond 3	Pond 4
11 May 73	Composite	6.8	5.6	5.6	9.4
29 May 73	Composite	6.4	7.8	8.0	12.4
18 Jun 73	Composite	16.2	5.4	11.2	12.4
2 Jul 73	Composite	10.4	10.4	10.2	9.0
23 Jul 73	Composite	8.6	8.8	10.2	12.2
21 Aug 73	Composite	6.4	10.0	6.0	33.7

SUSPENDED SOLIDS
(mg/1)

Date	Type of Sample	Pond 1	Pond 2	Pond 3	Pond 4
11 May 73	Composite	20.6	19.0	14.8	30.4
29 May 73	Composite	11.6	20.2	15.4	21.0
18 Jun 73	Composite	17.0	18.4	25.0	33.2
2 Jul 73	Composite	21.0	17.4	16.8	12.8
23 Jul 73	Composite	16.0	19.2	18.2	22.4
21 Aug 73	Composite	16.0	17.4	24.4	35.3

Composite refers to a) surface and middle samples at station A
b) surface and middle samples at station B
c) surface, middle, and depth samples at station C
(reference Figure 5 this report)

APPENDIX C19

PERIPHYTON SPECIES LIST - 1972 and 1973

8/9/72

number per square centimeter	Pond 1A	Pond 1C	Pond 2A	Pond 2C	Pond 3A	Pond 3C	Pond 4A	Pond 4C
Achnanthes lanceolata	2078	12337	895	514	6853	8399	429	268
A. minutissima	10661	40070	6123	5710	7567	10777	2860	2785
Amphipleura pellucida	1039	851	706	1999				
Amphora ovalis				57	1571	792	215	
Cocconeis placentula	3118	1064		114			72	
Caloneis amphisbaena								
Cyclotella meneghiniana	650					158		
C. stelligera	14289	8933	5888	8965	1713	2377	1645	1000
Cymbella microcephala	4626	18505	1225	4168	2427	1902	572	571
C. sp.	260				286	1902	501	357
C. turgida						158		
Diatoma elongatum								
D. vulgare					428			
Diploneis puella	909	213	236	114		316		
Epithemia zebra	2338	426	1366	514	286	632	215	54
Fragilaria sp.	260		612	856	572	158	72	54
F. brevistriata	6235	3616	612	343	1427	1426	215	216
F. crotonensis	1948		94	171	1142	1109		71
F. harrisonii			188	228	143	158		
F. pinnata								
Gomphonema acuminatum			94					
G. angustatum								
G. constrictum								
G. olevaceum	390	1489	236	286	428	158	48	71
G. sp.								
Mastogloia braunii	2078	2130						
Melosira varians								
Navicula capitata	260							
N. radiosa	650	213	141	228	286	951		54
N. rhynchocephala								
N. tripunctata	1169	213	282	628	428	475	72	54
N. viridula	779	213			286			
Nitzschia acicularis	909		141		5711	22504	858	1071
N. filiformis	5326	9907	2261	2969	11851	6707	501	428
N. fonticola								
N. hungarica	130							
N. linearis	130							
N. palea	1819	1276	848	742	3284	3962	429	589
N. paradoxa								
N. parvula								
Opephora martyi	390	213	94					

APPENDIX C_{19} (cont.)

8/9/72	Pond 1A	Pond 1C	Pond 2A	Pond 2C	Pond 3A	Pond 3C	Pond 4A	Pond 4C
Continued								
Pinnularia abaujensis								
Pleurosigma delicatulum								
Rhopalodia gibba	520	1914	518	914		1109	1216	518
Surirella angusta								
S. ovata								
Synedra acus								
S. sp. 1	7534	1276	706	742	8710	13312	1287	1232
S. sp. 2	1559	213	330	286	16705	1580	72	143
S. nana								
S. ulna								

APPENDIX C_{19} (cont.)

9/8/72 number per square centimeter	Pond 1A	Pond 1C	Pond 2A	Pond 2C	Pond 3A	Pond 3C	Pond 4A	Pond 4C
Achnanthes lanceolata	1428	1899	1148	1189	3141	1784	1214	2213
A. minutissima	15420	11964	4018	4995	7996	7136	5426	5426
Amphipleura pellucida	1999	950	861	832				71
Amphora ovalis				476		178		
Cocconeis placentula								357
Caloneis amphisbaena								
Cyclotella meneghiniana	5711		1913	714	286	178	71	714
C. stelligera	79957	46526	22958	27116	29555	17126	10994	11994
Cymbella microcephala	3712	1329	478	1189	1999	1160	1428	785
C. sp.	2856	1139			143	178	571	714
C. turgida		760						
Diatoma elongatum							143	
D. vulgare	286	1139	957	832	572		357	
Diploneis puella	572	380	383	714	1285	268	428	
Epithemia zebra	2856	1139		238			1642	357
Fragilaria sp.	2856	950	383	238.	572	268	785	1142
F. brevistriata	2856	1709	287	476	428		214	214
F. crotonensis	857	950	383	832	286	446	357	500
F. harrisonii					143	178	214	214
F. pinnata								
Gomphonema acuminatum			96					286
G. angustatum			861	595				428
G. constrictum			383		143			500
G. olevaceum		380	3252	476	4141	2141	999	2927
G. sp.								
Mastogloia braunii								
Melosira varians								428
Navicula capitata							71	214
N. radiosa	5426	1519	957	714	1999	1249	1142	357
N. rhynchocephala								
N. tripunctata	2856	1709		951				357
N. viridula	857	1899	287	476	714		143	500
Nitzschia acicularis	5711	3228	1148	714	2860	1070	500	928
N. filiformis	7425	3798	4305	5946	3427	535	1428	1214
N. fonticola								
N. hungarica	572	380						
N. linearis				238			71	71
N. palea	9423	6836	4305	4281	6282	2765	2284	2356
N. paradoxa								
N. parvula			191				143	
Opephora martyi								

APPENDIX C_{19} (cont.)

9/8/72	Pond 1A	Pond 1C	Pond 2A	Pond 2C	Pond 3A	Pond 3C	Pond 4A	Pond 4C
Continued								
Pinnularia abaujensis								
Pleurosigma delicatulum								
Rhopalodia gibba	1142	950	96					71
Surirella angusta								
S. ovata								
Synedra acus				238			71	
S. sp. 1	8852	4937	3444	4876	7139	10972	5568	3784
S. sp. 2	857	380		357	572			286
S. nana								
S. ulna								

APPENDIX C_{19}(cont.)

9/23/72

number per square centimeter	Pond 1A	Pond 1C	Pond 2A	Pond 2C	Pond 3A	Pond 3C	Pond 4A	Pond 4C
Achnanthes lanceolata	501	338	1142	214	535	571	857	1856
A. minutissima	2098	1690	2162	3462	1213	942	5426	6782
Amphipleura pellucida	477	286	612	286				
Amphora ovalis						29	286	
Cocconeis placentula		78				143	286	214
Caloneis amphisbaena		78						
Cyclotella meneghiniana		78	204	214		286	500	428
C. stelligera	2122	3042	898	1106	1106	2427	1856	856
Cymbella microcephala								
C. sp.	72	338		178	178	228	1428	357
C. turgida			245	178				
Diatoma elongatum				36				
D. vulgare								
Diploneis puella		130	122	108	108		143	286
Epithemia zebra	405	364	2203	178	1428	228	428	2856
Fragilaria sp.								
F. brevistriata								
F. crotonensis				143	250	742		428
F. harrisonii							286	
F. pinnata		338						
Gomphonema acuminatum	882	130	82	357	143			71
G. angustatum	477	104						
G. constrictum	2599	754	3264	3248	2748	1399	4712	2927
G. olevaceum	95	26	938	214	1428	571	1142	999
G. sp.	286	546	2938	2570	2784	1627	2713	1499
Mastogloia braunii							714	428
Melosira varians	95	286	82			114	571	428
Navicula capitata								
N. radiosa	477	598	571	250	250	228	214	428
N. rhynchocephala	95	156				143		
N. tripunctata	72	104	41			286	286	428
N. viridula			82	214			71	
Nitzschia acicularis							214	
N. filiformis	1931	1066	775	642	428	143	428	214
N. fonticola	72	338						
N. hungarica								
N. linearis				71		29		
N. palea	286	728	245	428	357	143		714
N. paradoxa		104	163	214			428	286
N. parvula			122	143				
Opephora martyi	286	78	245	428	214		571	714

APPENDIX C_{19} (cont.)

9/23/72	Pond 1A	Pond 1C	Pond 2A	Pond 2C	Pond 3A	Pond 3C	Pond 4A	Pond 4C
Continued								
Pinnularia abaujensis								
Pleurosigma delicatulum	72	104					143	
Rhopalodia gibba					108		286	
Surirella angusta								
S. ovata		26	41					
Synedra acus								
S. sp. 1	358	754	122	535	3069	3483	13992	13707
S. sp. 2				357	108		286	428
S. nana					36	86		
S. ulna								

APPENDIX C_{19} (cont.)

10/13/72

number per square centimeter	Pond 1A	Pond 1C	Pond 2A	Pond 2C	Pond 3A	Pond 3C	Pond 4A	Pond 4C
Achnanthes lanceolata	571	3157	571	571	971	1856	437	1208
A. minutissima	6140	8801	32268	30840	5938	18704	9605	23497
Amphipleura pellucida	714	1818	1285	1142	171			
Amphora ovalis		96		286			79	220
Cocconeis placentula								
Caloneis amphisbaena								
Cyclotella meneghiniana		957	286	1142	457	214	159	220
C. stelligera	9352	12627	1856	4997	1713	785	476	1318
Cymbella microcephala	714	478	571	857	852	286	318	439
C. sp.	500	670	571	428	571	286	397	1208
C. turgida								
Diatoma elongatum								
D. vulgare								
Diploneis puella	214	765	1142	999	114			659
Epithemia zebra		96		571	286	714	79	
Fragilaria sp.								
F. brevistriata								
F. crotonensis	714	1531	999	857	571		318	1098
F. harrisonii								
F. pinnata	71			857				
Gomphonema acuminatum	428	1435	1713	1999	171			110
G. angustatum					400			
G. constrictum	4498	7940	11565	12422	1142	1642	1111	2416
G. olevaceum	3141	2870	7139	2998	3140	2142	238	1098
G. sp.	2784	1913	6853	4997	3198	2570	1151	1537
Mastogloia braunii								
Melosira varians		191						
Navicula capitata	143						40	
N. radiosa	571	574	857	1142	457	143	714	1537
N. rhynchocephala								
N. tripunctata		191					159	
N. viridula	286	191	857	428			119	439
Nitzschia acicularis								659
N. filiformis	571	2009	571	571	514	928	198	988
N. fonticola			286	286	57	143		220
N. hungarica								
N. linearis								
N. palea	714	2296	571	857	856	999	397	769
N. paradoxa	286	191					159	
N. parvula		191						
Opephora martyi	857	383	1428	571	571		318	1098

APPENDIX C_{19} (cont.)

10/13/72

Continued	Pond 1A	Pond 1C	Pond 2A	Pond 2C	Pond 3A	Pond 3C	Pond 4A	Pond 4C
Pinnularia abaujensis							794	4612
Pleurosigma delicatulum				143				
Rhopalodia gibba	428	383	428	286				
Surirella angusta								
S. ovata								110
Synedra acus								
S. sp. 1	1499	2392	857	1142	4739	4069	3651	13725
S. sp. 2		670		286	171		40	439
S. nana								
S. ulna								

APPENDIX C_{19} (cont.)

11/3/72

number species per centimeter	Pond 1A	Pond 1C	Pond 2A	Pond 2C	Pond 3A	Pond 3C	Pond 4A	Pond 4C
Achnanthes lanceolata	113	285	678	286	100	333	125	
A. minutissima	267	1178	6888	14849	1216	983	1267	942
Amphipleura pellucida	82	627	464	1214			71	
Amphora ovalis	9	57	36		14		143	
Cocconeis placentula								
Caloneis amphisbaena							54	
Cyclotella meneghiniana	6	95	36	71	186			
C. stelligera	170	1463	2141	3641	143	238	268	286
Cymbella microcephala	3	57	143		43	48	286	
C. sp.	9	57		571	72	48	161	86
C. turgida								
Diatoma elongatum								
D. vulgare							71	
Diploneis puella		38				16		
Epithemia zebra	22	57	286	286	14	32	232	228
Fragilaria sp.	126	437	71				375	714
F. brevistriata			71					
F. crotonensis	50		785	2284	286	380	500	57
F. harrisonii			143			48	54	
F. pinnata								
Gomphonema acuminatum	19	95		428		48		
G. angustatum								
G. constrictum	85	285	1285	1356	329	238	268	86
G. olevaceum	38	330	428	3070	43	238	357	
G. sp.	78	323	1671	2499	386	143	89	114
Mastogloia braunii								
Melosira varians		152		286	186	238	196	
Navicula capitata		57						
N. radiosa	141	589	214	428	143	190	357	371
N. rhynchocephala							89	
N. tripunctata			428	143	72	16		
N. viridula	57	133	214	428		48	71	
Nitzschia acicularis						95		
N. filiformis	91	760	71	286	243	206	214	200
N. fonticola	3		286	428		48	232	
N. hungarica		95	214	214			21	
N. linearis								
N. palea	85	323	642	571	186	428	286	114
N. paradoxa		95					71	
N. parvula			71					
Opephora martyi		38	143	286	14	143	232	86

APPENDIX C_{19} (cont.)

11/3/72	Pond 1A	Pond 1C	Pond 2A	Pond 2C	Pond 3A	Pond 3C	Pond 4A	Pond 4C
Continued								
Pinnularia abaujensis			71				54	57
Pleurosigma delicatulum								29
Rhopalodia gibba	9	57		71	28		125	
Surirella angusta			143					
S. ovata	9	19						
Synedra acus								
S. sp. 1	57	323	928	857	2960	2520	3267	9992
S. sp. 2	9	152	71	71	114	95	143	371
S. nana								
S. ulna	85	456	357	286		48	54	

APPENDIX C_{19} (cont.)

11/30/72

number species per contimeter	Pond 1A	Pond 1C	Pond 2A	Pond 2C	Pond 3A	Pond 3C	Pond 4A	Pond 4C
Achnanthes lanceolata	29	95	857	214		71	428	143
A. minutissima	1673	1315	4318	13350	4283	1285	20060	19347
Amphipleura pellucida	96	95	1820	3355				143
Amphora ovalis								
Cocconeis placentula			71		214			
Caloneis amphisbaena								
Cyclotella meneghiniana	29	36	286	500	143			
C. stelligera	860	1695	2034	2070	714	286	428	643
Cymbella microcephala		36	36	286	286	71	571	143
C. sp.			107	214			371	214
C. turgida	478							
Diatoma elongatum	48		214					
D. vulgare						71		
Diploneis puella	10		107	214	143	71	286	
Epithemia zebra	134	36	286	286		54		
Fragilaria sp.	392	474	1820	2499	1571	339	214	3070
F. brevistriata			143					71
F. crotonensis			143	642				
F. harrisonii			107					143
F. pinnata								
Gomphonema acuminatum				642	371			
G. angustatum								
G. constrictum	182	95	428	785	928	178	928	286
G. olevaceum	96		71	500	371	36		
G. sp.	29	213	464	1142	286	143	857	286
Mastogloia braunii								
Melosira varians		142	71	500	428	214	642	
Navicula capitata			71	500				
N. radiosa	96	95	1178	1499	71	36	1142	371
N. rhynchocephala		130	107	999				
N. tripunctata			71			54		
N. viridula			71		214			
Nitzschia acicularis		36					1642	571
N. filiformis	277	521	749	999		286	1214	714
N. fonticola		36	428	286	143			
N. hungarica			71	143			143	
N. linearis								
N. palea	239	95	464	571	428		500	643
N. paradoxa			214					
N. parvula								
Opephora martyi		178	286	357	286			143

APPENDIX C_{19} (cont.)

11/30/72	Pond 1A	Pond 1C	Pond 2A	Pond 2C	Pond 3A	Pond 3C	Pond 4A	Pond 4C
Continued								
Pinnularia abaujensis			71					
Pleurosigma delicatulum			143					
Rhopalodia gibba			36	286				
Surirella angusta		12	71	357				
S. ovata						89		
Synedra acus								
S. sp. 1	296	1422	1178	2641	17919	4998	4355	3641
S. sp. 2	19	24	428	357	2070	464	1428	714
S. nana					2356		4283	7139
S. ulna	19		286	500	571	36	286	

APPENDIX C_{19} (cont.)
DIATOM SPECIES PROPORTIONAL COUNT - July 2, 1973
(abundance as percent relative to total cells counted)

	1A	1C	2A	2C	3A	3C	4A	4C
Total Cells Counted	530	515	552	362	477	340	336	330
Achnanthes Bory (girdle view)	7.5	14.6	35.0	29.3	2.3	3.0	2.4	1.8
A. exilis Kuetz.			0.2					
A. lanceolata var. dubia Grun.			0.2					
A. lanceolata (Breb.) Grun. var. lanceolata	0.2	0.4			0.2			
A. linearis f. curta H. L. Sm.			0.4					
A. linearis (W. Smith) Grun. var. linearis	14.9	13.8		1.4	11.5	10.6	2.7	2.4
A. minutissima Kuetz. var. minutissima	35.8	45.0	33.0	44.2	10.1	5.6	5.7	2.7
Amphipleura pellucida Kuetz. var. pellucida	2.5	1.2	1.1	0.3				0.3
Amphora sp. Ehr.	0.2		0.2		0.2			
Caloneis ventricosa var. truncatula (Grun.) Meist.					0.2			
C. schumanniana (Grun.) Cleve						0.3		
Cyclotella comta (Ehr.) Kuetz.			0.4	0.3	0.4	1.8	2.1	1.5
C. bodanica Eulenst					0.2			
C. glomerata Bach.	3.8	0.8	3.8	0.6	10.7		22.0	3.3
C. meneghiniana Kuetz.	0.4	0.2	0.5		0.8	1.2	0.3	0.3
C. stelligera Cl. in Grun.	0.2		0.2			6.5		16.7
Cymatopleura solea (Breb.) W. Smith	0.2		0.5					
Cymbella affinis Kuetz.	0.4	4.5	0.5	3.9	0.2			
C. microcephala Grun.	4.7	2.9	0.5	3.6	3.8	2.0	1.5	0.6
C. parva (W. Smith) Cl.			0.2					
C. tumidula Grun.			0.4					
C. (c.f. turgidula) Grun.	0.2							
C. ventricosa Kuetz.	0.2							
Diploneis elliptica (Kuetz.) Cl. var. elliptica		0.2		0.3				
D. pseudovalis Hust. var. pseudovalis			1.4					
Epithemia zebra (Ehr.) Kuetz.	1.1	0.8	0.4		0.8	0.2		
Eunotia sp. Ehr.			0.2					
Fragilaria Lyng. (girdle view)			0.7					
F. construens var. binodes (Ehr.) Grun.				0.3				
F. lepostauron var. dubia (Grun.) Hust.			0.2					
Gomphonema sp. Agardh				0.6	0.2			
G. (girdle view)	0.4		0.2					
G. acuminatum Ehr.	0.6		0.4					
G. angustatum (Kuetz.) Rabh.	0.4	0.2						
G. parvulum Kuetz.	0.7							
Gyrosigma sp. Hassall					0.2			
G. acuminatum (Kuetz.) Rabh. var. acuminatum	0.5							

APPENDIX C$_{19}$ (continued)
Diatom Species Proportional Count - July 2, 1973
(abundance as percent relative to total cells counted)

	1A	1C	2A	2C	3A	3C	4A	4C
Hantzschia amphioxys (Ehr.) Grun.					0.2	0.3	0.3	0.3
Mastogloia smithii var. *amphicephala* Grun.	0.2	0.2						
Navicula sp. Bory	0.2	0.4						
N. anglica var. *subsalsa* (Grun.) Cl.			0.2					
N. arvensis Hust. var. *arvensis*					0.2			
N. capitata Ehr. var. *capitata*				0.3				
N. cincta (Ehr.) Ralfs var. *cincta*	0.4		0.2					
N. cryptocephala Kuetz. var. *cryptocephala*	0.2	0.6	0.5		1.5	1.8		0.3
N. cryptocephala var. *veneta* (Kuetz.) Rabh.	1.3	0.2		0.3	0.2			
N. cuspidata (Kuetz.) Kuetz. var. *cuspidata*	0.8							
N. gottlandica Grun. var *gottlandica*		0.2						
N. graciloides A. Mayer var. *graciloides*		0.2			0.6	2.4	0.9	
N. laevissima Kuetz. Laevissima	0.2							
N. lyra Ehr. var. *Lyra*						0.6	0.3	0.3
N. menisculus var. *upsaliensis* (Grun.) Grun.	0.6	0.4	0.5	0.3	1.3	0.3	2.1	0.6
N. minima Grun. var. *minima*								0.3
N. pseudoreinhardtii Patr. var. *pseudoreinhardtii*					0.4			0.3
N. pupula var. *rectangularis* (Greg.) Grun.	0.2				0.4	0.9		
N. radiosa var. *parva* Wallace								0.3
N. radiosa var. *tenella* (Breb. *ex* Kuetz.) Grun.		0.2						
N. rhyncocephala Kuetz. var. *rhyncocephala*	0.8							
N. texana Patr. var. *texana*	0.2							
N. tripunctata (O.F. Muell.) Bory var. *tripunctata*			0.2		0.2			
Neidium binode (Ehr.) Hust. var. *binoda*					0.2	0.3		0.3
Nitzschia acicularis W. Smith	0.8		0.2		10.9	7.0	16.4	27.9
N. angustata (W. Smith) Grun.			0.2	0.3	0.4		0.3	
N. capitella Hust.	0.2							
N. clausii Hantz.	0.2							
N. dissipata (Kuetz.) Grun.	0.9		0.5	0.6	2.3	3.8	1.8	2.4
N. filiformis (W. Smith) Hust.		0.2			0.4	0.9		
N. fonticola Grun.	0.4	0.8	0.4			0.6	0.3	0.3
N. frustulum Kuetz.	5.5	4.1	8.5	6.6	16.8	26.9	14.0	23.6
N. hungarica Grun.	0.6					2.0	0.3	0.3
N. kuetzingiana Hilse					0.8			
N. linearis W. Smith	2.1	1.2	0.7		5.9	4.4		0.3
N. palea (Kuetz.) W. Smith	5.1	2.5	1.3	0.3	6.5	2.6	5.4	2.7
N. sinuata (W. Smith) Grun.					0.2	0.6		1.5
N. tryblionella Hantz.			0.2					
Pinnularia Ehr. sp.			0.2					
Rhoicosphenia curvata (Kuetz.) Grun			0.4	0.6				

APPENDIX C$_{19}$ (cont.)
DIATOM SPECIES PROPORTIONAL COUNT - July 2, 1973
(abundance as percent relative to total cells counted)

	1A	1C	2A	2C	3A	3C	4A	4C
Continued -								
Stephanodiscus astraea (Ehr.) Grun.	0.2		0.2			0.3	0.3	
Synedra Ehr. (girdle view)				0.6				
S. amphicephala var. *austriaca* (Grun.) Hust.						0.3		
S. (c.f. *affinis* Kuetz.)		2.9						
S. crotonensis var. *prolongata* Grun. *in*. V. H.	7.2	1.4	4.7	5.8	8.0	11.2	20.8	6.4
S. delicatissima W. Smith var. *delicatissima*						1.8		2.1
S. radians Kuetz. var. *radians*	0.2							
S. rumpens var. *familiaris* (Kuetz.) Hust.						0.6		
S. rumpens var. *scotia* Grun.					0.2			
S. tenera W. Smith var. *tenera*					0.2			
S. ulna var. *chaseana* Thomas		0.2						
S. ulna (Nitz.) Ehr. var. *ulna*			0.5					

APPENDIX C_{19} (cont.)
Diatom Species Proportional Count - August 17, 1973
(abundance as percent relative to total cells counted)

TOTAL CELLS COUNTED	1A 292	1C 305	3A 310	3C 320	4A 317	4C 356
Achnanthes Bory (girdle view)	12.3	14.8	12.6	15.6	47.3	17.7
A. lanceolata (Breb.) Grun. var. *lanceolata*	0.7					0.3
A. linearis f. *curta* H. L. Sm.					8.5	5.9
A. linearis (W. Smith) Grun. var *linearis*	2.4	5.9	9.0	9.1		
A. minutissima Kuetz. var. *minutissima*	12.3	15.1	9.4	11.9	19.6	29.8
Amphipleura pellucida Kuetz. var. *pellucida*	1.7	0.7				
Cyclotella (c.f. *catenata* Brun.)			1.3			
C. comta (Ehr.) Kuetz.		1.6	0.6	1.6		1.1
C. glomerata Bach.	7.5	10.2	19.0	19.4	8.2	15.7
C. meneghiniana Kuetz.		1.3		0.3	0.3	
C. stelligera Cl. *in* Grun.	5.5					0.8
Cymbella affinis Kuetz.		0.3				
C. microcephala Grun.	2.4	2.3	4.2	2.5	0.6	0.6
Denticula thermalis Kuetz.			0.6			
Diploneis sp. Ehr.						0.3
Epithemia zebra (Ehr.) Kuetz.				0.3		
Fragilaria (Lyng.) girdle view	2.0					
Gomphonema intricatum Kuetz.				0.3		
G. olivaceum (Lyng.) Kuetz.				0.3		
Gyrosigma sp. Hassall		0.3				
Mastogloia sp. Thwaites					0.6	
Melosira italica (Ehr.) Kuetz.	1.4	1.0				
Navicula sp. Bory	0.3	1.0			0.6	
N. arvensis Hust. var. *arvensis*						0.3
N. capitata Ehr. var. *capitata*			0.3			
N. cryptocephala Kuetz. *cryptocephala*	0.7	1.6	1.0	1.3		1.7
N. cryptocephala var. *veneta* (Kuetz.) Rabh.	0.7		0.3			
N. cuspidata (Kuetz.) Kuetz. var. *cuspidata*		0.3				
N. falaisiensis Grun.			0.3			
N. graciloides A. Mayer var. *graciloides*	0.7	0.3	1.0	0.9	0.9	0.3
N. lyra Ehr. var. *lyra*		0.3				
N. menisculus var. *upsaliensis* (Grun.) Grun.	2.0		0.3			
N. minima Grun. var. *minima*	1.0	0.7	0.3	0.9	1.3	0.8
N. odiosa Wallace var. *odiosa*			0.6			
N. pseudoreinhardtii Patr. var. *pseudoréinhardtii*	0.3		0.6			
N. pupula var. *elliptica* Hust				0.3		
N. pupula Kuetz. var. *pupula*		0.3				0.3
N. rhyncocephala Kuetz. var. *rhyncocephala*		0.3				
N. vitabunda Hust.				1.3		
Neidium binode (Ehr.) Hust. var. *binode*				0.3		
Nitzschia acicularis W. Smith	2.4	1.3	1.9	0.6		

APPENDIX C_{19} (cont.)
Diatom Species Proportional Count - August 17, 1973
(abundance as percent relative to total cells counted)

	1A	1C	3A	3C	4A	4C
Nitzschia amphibia Grun.		0.3				
N. angustata (W. Smith) Grun.	0.7					
N. dissipata (Kuetz.) Grun.	1.7	1.3		0.3	0.3	
N. filiformis (W. Smith) Grun.	2.0		1.6			
N. fonticola Grun.	7.9	0.3				0.3
N. frustulum Kuetz.	18.8	16.4	7.7	11.6	2.2	9.6
N. hungarica Grun.	0.3					
N. kuetzingiana Hilse		3.3	15.8	9.4	2.2	3.4
N. linearis W. Smith	3.4	1.6	3.9	2.8		0.6
N. palea (Kuetz.) W. Smith	5.8	13.8	4.2	2.5		2.2
N. sinuata (W. Smith) Grun.	0.3			0.3	0.3	0.6
N. sublinearis Hust.		0.3			0.3	
N. thermalis Kuetz.					0.3	0.3
Pinnularia Ehr. sp.		0.3				
Stephanodiscus Ehr. sp.	0.3					
S. astraea (Ehr.) Grun.			0.6			
Synedra crotonensis var. *prolongata* Grun. *in* V. H.		2.0	2.6	6.3	6.3	6.7
S. delicatissima W. Smith var. *delicatissima*	2.0					0.8
S. rumpens var. *scotia* Grun.		0.7				

APPENDIX C_{20}

Pond #1: PHYTOPLANKTON BIOMASS (μg/l) 1971

Date:	8/14	8/27	9/14	9/19	9/21	9/28	10/5	10/12	10/19	11/2
EUPLANKTERS										
Ceratium hirundinella	27.6	62.1	188.6	165.6	105.8	4.6	27.6	4.6	4.6	4.6
Rhodomonas minuta	2.42	14.8	3.98	27.4	16.5	1.01	1.26	10.6	3.22	.743
Crytomonas erosa	1.21	1.30	6.08	1.11	6.08	.201	2.08	38.4	7.80	.975
Cryptomonas ovata		.256					.256	.769		
Dinobryon divergens	.065									
Dinobryon sociale								.139	1.86	76.0
Dinobryon bavaricum									6.30	85.5
Mallomonas akrokomos					.146	2.35	.994	2.98		
Kephyrian spirale						.336	.528			
Kephyrion ovale						1.34			22.6	
Volvox globator		12.3								
Scenedesmus spp.		.017	.067	.134	.101	.134	.134	.101	.101	.134
Sphaerocystis Schroeteri	.471	1.645	.888	.605	.362	.323				
Ankistrodesmus falcatus	.0155	.008		.031		.031	.0465			.062
Closterium venus					.021	.042	.021	.021		
Trachelomonas volvocina			.0214			.0214	.0428			
Cyclotella comta	2.82									
TYCHOPLANKTERS										
Achnanthes minutissima	.656	1.162	.107	.512	3.5	2.11	1.51	1.15	1.63	3.2
Rhopalodia gibba			.908	.454	2.72	.908	.454	1.36	.908	.908
Epithemia zebra					1.82	.91	3.64	.91	1.82	
Synedra ulna	2.6		2.6		18.2	6.5	2.6	5.2	5.2	3.9
Synedra delicatissima	1.43		1.017	12.64	21.64	10.15	6.48	4.14	3.75	1.29
Synedra tenera		.066	.198	.242	1.89	1.23	.616	.308	.308	.198
Cymbella cistula	.178	2.67	2.04	1.96	4.0	3.03	7.84	1.07	6.4	3.47
Gomphonema spp.	.364	.072	1.497	.072	3.18	1.72	5.33	1.73	.426	.422
Gyrosigma sp.										6.27

APPENDIX C_{20} (cont.)

Pond #2: PHYTOPLANKTON BIOMASS (μg/l) 1971

Date:	8/14	8/27	9/14	9/19	9/21	9/28	10/5	10/12	10/19	11/2
EUPLANKTERS										
Ceratium hirundinella	36.8	82.8	174.8	138.0	69.0	46.0	41.4	9.2		4.6
Rhodomonas minuta	.845	8.615	139.0	94.0	94.0	39.8	9.40	68.7	16.0	2.98
Cryptomonas erosa	.538	1.225	11.5	4.0	11.6	26.0	48.5	157.0	50.8	.034
Cryptomonas ovata		.51				5.9	1.79		17.9	.256
Dinobryon divergens	.065		.585							
Dinobryon sociale								.109	1.18	44.5
Dinobryon bavaricum									2.68	25.0
Mallomonas akrokomos					1.12	.832	.015	2.60	2.09	.015
Kephyrion spirale						8.65	1.49			
Kephyrion ovale							4.86		10.5	7.10
Volvox globator	6.93	126.8								
Scenedesmus spp.	.134		.403		.101	.369	.134			.034
Sphaerocystis Schroeteri	1.26	.345	.670	.262	.323	.807	.027			
Ankistrodesmus falcatus	.016			.124				.062		
Closterium venus		.32	2.1				.21			
Trachelomonas volvocina		.214	1.07	.214	.642	1.71	2.36	.642		
Cyclotella comta	1.44									
TYCHOPLANKERS										
Achnanthes minutissima	1.57	6.36	3.51	1.39	3.60	1.79	3.24	.993	.64	.032
Rhopalodia gibba		2.72	15.9	1.36	.454	1.36	5.45	2.72	4.54	.91
Epithemia zebra			3.64	2.73	2.73	2.73	28.2	14.5	9.1	.91
Synedra ulna	5.2		186.0		2.6	10.4	16.9	14.3	3.9	1.3
Synedra delicatissima	.238	1.94	41.55	.238	2.55	4.52	8.69	8.50	4.24	2.58
Synedra tenera	.154	.617	16.7	1.3	.705	1.94	1.70	.925	.507	
Cymbella cistula	.178	1.20	20.7	1.87	3.82	6.58	12.4	1.33	13.7	.8
Gomphonema spp.	6.74	1.82	10.5	1.08	11.78	3.60	12.54	7.29	2.20	.42

APPENDIX C_{20} (cont.)

POND #3: PHYTOPLANKTON BIOMASS (μg/l) 1971

Date:	8/14	8/27	9/14	9/19	9/21	9/28	10/5	10/12	10/19	11/2
EUPLANKTERS										
Ceratium hirundinella	510.6	308.2	13.8	9.2						
Rhodomonas minuta	4.45	35.15	110.0	25.0	124.0	.364	1.48	4.19	.377	
Cryptomonas erosa	5.82	4.11	7.9	1.48	7.27	.101	2.28	11.5	.808	2.72
Cryptomonas ovata						.256		.256		
Dinobryon divergens	49.1	2.74								
Dinobryon sociale						.125	.062	1.72	9.64	89.4
Dinobryon bavaricum									10.9	151.0
Mallomonas akrokomos						3.97	1.88	3.16	3.34	
Kephyrion spirale						.77	2.45	10.8		
Kephyrion ovale						3.95				
Scenedesmus spp.	.034	.034			.067	.034				.034
Sphaerocystis Schroeteri		.130								
Ankistrodesmus falcatus			.357	.078	.171	.078	.233	.012		
Closterium venus							.21			
Trachelomonas volvocina		.107	.428	.214						
TYCHOPLANKTERS										
Achnanthes minutissima	.144	1.66	1.47	1.86	7.35	3.04	1.60	1.80	1.70	.032
Rhopalodia gibba	.454	.227	.908	7.71		3.63	.454	2.27	.908	
Epithemia zebra			.91	4.55	.91	7.28	4.05	3.64	3.64	
Synedra ulna			1.3	1.3					5.2	
Synedra delicatissima			.357	.119	.357	1.80	.357	1.26	.511	
Synedra tenera		.044	.154	.132	.088	.044	.571	.220	.154	
Cymbella cistula			.267	2.31	3.38	5.16	16.6	2.32	5.16	.178
Gomphonema spp.	.432	.903	.775	1.71	5.90	1.15		3.44	6.44	1.30

APPENDIX C_{20} (cont.)

Pond #4: PHYTOPLANKTON BIOMASS (μg/l) 1971

Date:	8/14	8/27	9/14	9/19	9/21	9/28	10/5	10/12	10/19	11/2
EUPLANKTERS										
Ceratium hirundinella	115.0	370.3	13.8	13.8	18.4					
Rhodomonas minuta	8.38	44.55	89.5	17.7	75.9	15.8	26.4	20.8	8.95	4.66
Cryptomonas erosa	28.4	6.96	12.3	2.66	5.65	5.19	8.32	31.3	8.18	14.9
Cryptomonas ovata					1.79	.256	.256		.256	4.87
Dinobryon divergens	6.57	4.26	.065							
Dinobryon sociale						.062		.047	.296	4.05
Dinobryon bavaricum										2.29
Mallomonas akrokomos					.60	3.14		.365	.438	
Kephyrion spirale						1.73	.723		.064	
Volvox globator	5.60	4.40								
Scenedesmus spp.	.202	.084	.034	.067		.202	.101	.269	.168	
Sphaerocystis Schroeteri		.380	.108	.054	.134	.027	.175	.134		
Ankistrodesmus falcatus			.822	.109	.062	.062	.062	.155		
Closterium venus							.210			
Trachelomonas volvocina		.107	.214	.428						
TYCHOPLANKTERS										
Achnanthes minutissima	15.8	41.3	15.1	5.66	3.66	4.80	25.6	3.63	17.3	1.41
Rhopalodia gibba	9.08	1.36	2.27	7.71	1.82	6.36	15.0	5.90	23.6	3.18
Epithemia zebra			3.64	5.46	7.29	15.5	54.6	28.2	169.0	14.6
Synedra ulna	3.9			6.5		7.8	33.8	32.5	29.9	2.6
Synedra delicatissima	1.814	.705	.595	4.41	.339	2.154	23.0	99.1	14.67	2.017
Synedra tenera	.86	.176	.617	.419		.419	1.34	1.36	.705	
Cymbella cistula	.178	.222	1.33	3.11	1.16	3.47	67.5	17.7	66.2	5.43
Gomphonema spp.	3.44	2.67	4.90	5.83	6.609	16.12	13.73	9.63	4.33	.423

APPENDIX C_{20} (cont.)

Ponds #1-#4: PHYTOPLANKTON BIOMASS (μg/l) 1971

Date:	8/14	8/27	9/14	9/19	9/21	9/28	10/5	10/12	10/19	11/2
Pond #1										
Total	40.04	96.32	208.20	199.50	178.03	37.52	62.01	75.26	65.54	188.08
Tychoplankton	5.44	3.90	8.37	4.62	48.83	26.56	28.47	17.46	20.44	20.08
Euplankton	34.6	92.42	199.83	194.88	129.2	10.96	33.54	57.80	45.10	168.0
Euplankton *Ceratium*	4.18	30.0		29.0		6.36		53.2	42.0	
Productivity (cpm)	866	1474		679		(407)		(226)	(1008)	
Pond #2										
Total	66.30	235.43	628.65	246.57	205.69	162.99	199.31	289.09	139.98	91.47
Tychoplankton	18.27	14.65	298.52	9.97	28.90	32.92	89.12	50.78	38.83	6.95
Euplankton	48.03	220.78	330.13	236.60	176.79	130.07	110.19	238.31	101.15	84.52
Euplankton *Ceratium*	9.79	137.0		98.6		84.07		229.0	101.15	
Productivity (cpm)	551	3669		1382		(840)		(576)	(1635)	
Pond #3										
Total	571.43	353.74	138.63	55.66	158.92	32.15	32.74	35.79	54.25	244.66
Tychoplankton	1.03	3.26	6.15	19.69	18.21	22.50	24.14	14.95	18.39	1.51
Euplankton	570.40	350.48	132.48	35.97	140.71	9.65	8.60	20.84	35.86	243.15
Euplankton *Ceratium*	59.8	42.3		26.77						
Productivity (cpm)	1517	1208		578		(351)		(142)	(672)	
Pond #4										
Total	202.08	477.49	145.30	73.92	124.08	83.09	270.86	251.97	344.05	60.43
Tychoplankton	37.93	46.44	28.46	39.10	21.54	56.62	234.56	198.90	325.70	29.66
Euplankton	164.15	431.05	116.84	34.82	102.54	26.47	36.30	53.07	18.35	30.77
Euplankton *Ceratium*	49.15	60.0		21.02						
Productivity (cpm)	933	755		868		(920)		(527)	(657)	
Correlation Coefficients										
Productivity vs. Total	.933	-.430		.675		.776		.999	-.229	
Productivity vs. Tychoplankters	-.443	-.289		-.129						
Productivity vs. Euplankters	.939	-.432		.618		.592		.708	.977	
Productivity vs. Euplankters	.795	.882		.913		.674				

APPENDIX C_{21}

ABUNDANCE OF DOMINANT PHYTOPLANKTON GROUPS (no./ml)

Date	Dominant Group	Pond 1	Pond 2	Pond 3	Pond 4
28 July 72	Cyanophyta	23	23	0	0
	Chlorophyta	5426	2144	9880	8181
	Chrysophyta	869	2300	1826	1825
	Euglenophyta	107	136	498	316
	Pyrrhophyta	29	135	203	203
	Cryptophyta	10	0	68	45
	Bacillariophyta	266	429	1331	1961
	Other	0	0	0	0
4 Aug 72	Cyanophyta	241	184	107	145
	Chlorophyta	6555	2786	41487	40605
	Chrysophyta	1206	1496	2408	1371
	Euglenophyta	347	430	683	530
	Pyrrhophyta	68	48	628	367
	Cryptophyta	20	77	48	68
	Bacillariophyta	995	436	3661	2653
	Other	0	0	0	0
11 Aug 72	Cyanophyta	2003	1629	100	90
	Chlorophyta	14657	8565	8754	25998
	Chrysophyta	2188	1802	2406	1704
	Euglenophyta	117	992	1073	983
	Pyrrhophyta	10	70	843	908
	Cryptophyta	110	249	120	120
	Bacillariophyta	1907	1859	1884	1894
	Other	0	0	0	0
25 Aug 72	Cyanophyta	1622	1075	11	642
	Chlorophyta	9394	4796	15719	8935
	Chrysophyta	529	949	1905	2497
	Euglenophyta	514	839	470	1155
	Pyrrhophyta	75	84	629	454
	Cryptophyta	115	68	85	54
	Bacillariophyta	2645	1696	992	507
	Other	0	0	0	0
14 Sept 72	Cyanophyta	20	52	91	428
	Chlorophyta	2431	2814	5312	6530
	Chrysophyta	108	245	49	162
	Euglenophyta	188	313	519	487
	Pyrrhophyta	0	0	0	0
	Cryptophyta	261	58	71	196
	Bacillariophyta	874	587	21415	3355
	Other	0	0	0	0

APPENDIX C_{21}

ABUNDANCE OF DOMINANT PHYTOPLANKTON GROUPS (no./ml)

Date	Dominant Group	Pond 1	Pond 2	Pond 3	Pond 4
21 Sept 72	Cyanophyta	10	10	387	1053
	Chlorophyta	6061	4778	7590	8391
	Chrysophyta	251	175	4888	6994
	Euglenophyta	244	331	1032	871
	Pyrrhophyta	49	78	324	165
	Cryptophyta	203	454	125	58
	Bacillariophyta	2212	899	48295	17331
	Other	20	251	0	0
2 Oct 72	Cyanophyta	0	10	324	646
	Chlorophyta	4737	2378	9079	9884
	Chrysophyta	989	599	4337	1381
	Euglenophyta	58	58	735	486
	Pyrrhophyta	29	115	58	552
	Cryptophyta	105	0	0	0
	Bacillariophyta	743	440	6217	28052
	Other	0	0	0	0
6 Oct 72	Cyanophyta	19	0	77	314
	Chlorophyta	4916	3575	6873	8956
	Chrysophyta	1198	589	2368	1112
	Euglenophyta	87	167	221	334
	Pyrrhophyta	10	20	39	86
	Cryptophyta	0	0	0	0
	Bacillariophyta	555	724	2254	9452
	Other	67	0	10	10
17 Oct 72	Cyanophyta	20	0	50	126
	Chlorophyta	7759	13596	7500	8263
	Chrysophyta	946	821	222	425
	Euglenophyta	58	30	243	300
	Pyrrhophyta	0	0	39	19
	Cryptophyta	0	0	29	48
	Bacillariophyta	861	1256	1091	6568
	Other	0	0	0	0
24 Oct 72	Cyanophyta	0	0	98	39
	Chlorophyta	6911	9328	4560	7853
	Chrysophyta	425	859	39	68
	Euglenophyta	154	29	175	49
	Pyrrhophyta	19	0	116	10
	Cryptophyta	10	164	318	251
	Bacillariophyta	561	687	1757	868
	Other	19	0	0	0

APPENDIX C_{21}

ABUNDANCE OF DOMINANT PHYTOPLANKTON GROUPS (no./ml)

Date	Dominant Group	Pond 1	Pond 2	Pond 3	Pond 4
25 Apr 73	Cyanophyta	48	0	0	0
	Chlorophyta	2748	2253	9911	5631
	Chrysophyta	5046	1442	901	225
	Euglenophyta	135	631	0	225
	Pyrrhophyta	0	45	0	90
	Cryptophyta	135	135	90	496
	Bacillariophyta	3784	3199	9202	17436
	Other	0	0	0	0
14 May 73	Cyanophyta	0	90	856	1487
	Chlorophyta	4145	5677	3378	6081
	Chrysophyta	135	90	3019	8515
	Euglenophyta	45	45	586	135
	Pyrrhophyta	90	135	0	0
	Cryptophyta	0	45	676	811
	Bacillariophyta	1442	1036	2432	3153
	Other	0	0	0	0
21 May 73	Cyanophyta	45	0	225	315
	Chlorophyta	5226	8560	3784	3334
	Chrysophyta	991	0	405	496
	Euglenophyta	496	450	0	45
	Pyrrhophyta	45	0	45	0
	Cryptophyta	0	0	0	0
	Bacillariophyta	4605	5857	2568	3423
	Other	0	0	0	0
29 May 73	Cyanophyta	0	406	12390	0
	Chlorophyta	7118	4866	2027	2387
	Chrysophyta	180	405	225	180
	Euglenophyta	1126	405	0	90
	Pyrrhophyta	90	90	0	0
	Cryptophyta	0	0	0	0
	Bacillariophyta	6127	1937	1621	3333
	Other	0	0	0	0
5 June 73	Cyanophyta	0	0	6150	37959
	Chlorophyta	2792	4550	4686	2071
	Chrysophyta	90	270	90	90
	Euglenophyta	45	315	405	90
	Pyrrhophyta	45	45	45	135
	Cryptophyta	0	0	0	0
	Bacillariophyta	1892	766	2523	2658
	Other	0	0	0	0

APPENDIX C_{21}

ABUNDANCE OF DOMINANT PHYTOPLANKTON GROUPS (no./ml)

Date	Dominant Group	Pond 1	Pond 2	Pond 3	Pond 4
8 June 73	Cyanophyta	0	113	22099	22234
	Chlorophyta	12028	10045	5090	2927
	Chrysophyta	450	360	90	90
	Euglenophyta	135	585	0	45
	Pyrrhophyta	45	90	180	90
	Cryptophyta	0	0	0	0
	Bacillariophyta	4640	3199	4640	2207
	Other	0	0	0	0
14 June 73	Cyanophyta	135	45	47	1131
	Chlorophyta	14417	6171	30480	6566
	Chrysophyta	2342	1621	376	197
	Euglenophyta	180	360	188	124
	Pyrrhophyta	0	90	281	320
	Cryptophyta	0	0	0	344
	Bacillariophyta	34040	15027	37212	12547
	Other	0	0	0	0

PHYTOPLANKTON

(recorded as numbers per ml)

	28 Jul 72				4 Aug 72			
	Pond 1	Pond 2	Pond 3	Pond 4	Pond 1	Pond 2	Pond 3	Pond 4
Cyanophyta:								
Anabaena sp. Bory	23			68	29	29	19	19
A. viguieri Denis & Fremy								
Anabaenopsis elenkinii Miller					48	29		
Chroococcus dispersus (Keissl.) Lemm.					38	10	10	
Dactylococcopsis acicularis Lemm.								
Lyngbya sp. Agardh								
Merismopedia tenuissima Lemm.						20	20	
Microcystis aeruginosa Kuetz.								
Oscillatoria sp. Vaucher		23		23	126	96	58	126
O. acutissima Kufferath								
O. hamelii Fremy								
O. limnetica Lemmermann								
O. subbrevis Schmidle								
O. tenuis var. tergestina (Kuetz.) Rabenhorst								
Rhabdoderma sigmoidea fa. minor Moore & Carter								
Spirulina nordstedtii Gomont								
S. princeps (West & West) G. S. West	10							
Chlorophyta:								
Acanthosphaera zachariasi Lemm.								
Ankistrodesmus falcatus (Corda) Ralfs	164	23	2298	3470	956	464	22311	17167
A. spiralis (Turner) Lemm.	77	23	924	1284	367	290	11878	14970
Characium limneticum Lemm.	29			45				10
Chlamydomonas sp. Ehr.								
Chlorella vulgaris Beyerinck	3440	1149	924	834	2589	1366	3500	5860
Chodatella chodati (Bernard) Ley.	20		23	23	38	39		29
Cladophora sp. Kuetz.								
Closterium sp. Nitzsch	142	23			308	144	96	174
Cosmarium sp. Corda								10
Crucigenia quadrata Morren					10			
C. tetrapedia (Kirch.) West & West	10						512	338
Dictyosphaerium pulchellum Wood								
* Echinosphaerella limnetica G. M. Smith	42							
Euastrum Ehr.								
Franceia droescheri (Lemm.) G. M. Smith	10							
F. ovalis (France) Lemm.					58	20	232	29
F. tuberculata G. M. Smith				23				
Golenkinia radiata (Chod.) Wille	74	23	721	428	86	10	290	174
Green globose colony cf. Coelastrum Naegeli in Kuetz.	10							
Kirchneriella obesa (W. West) Schmidle					10			
Lagerheimia longiseta (Lemm.) Printz								10
L. quadriseta (Lemm.) G. M. Smith					10			
L. subsala Lemm.							10	20
Mougeotia sp. (C. A. Agardh) Wittrock	20				38			
Oedogonium sp. Link	90		68	45				
* Oocystis eremosphaeria G. M. Smith	10							
O. gloeocystiformis Borge	23				10	10		
Pandorina morum (Muell.) Bory								
Pediastrum duplex Meyen							10	
P. tetras (Ehren.) Ralfs	39	68			78		20	29
Planktosphaeria gelatinosa G. M. Smith								10
Pleurotaenium Naeg.	32							
Scenedesmus abundans (Kirch.) Chodat	55		608	946	87	10	706	434
S. bijuga (Turp.) Lagerheim	315	158	406	428	676	86	782	463
* S. dimorphus (Turp.) Kuetz.		23	68	23	96		38	48
S. quadricauda (Turp.) de Brebisson in de Brebisson & Godey			113	45	19		48	38
Scenedesmus sp. (2 spines)	10				19	10	20	10
Schroederia setigera (Schroed.) Lemm.								10
Selenastrum minutum (Naeg.) Collins	322	225	135	474	685	183	898	685
Spondylosium sp. de Brebisson								
Staurastrum americanum (Bohlin) Schmidle								19
Tetradesmus wisconsinense G. M. Smith								
Tetraedron duospinum Ackley								
T. minimum (A. Braun) Hansgirg	132	406	23		376	154	87	29
T. regulare Kuetz.					10		10	
T. trigonum (Naeg.) Hansgirg			45		19			
Tetrastrum staurogeniaeforme (Schroeder) Lemm.								
Treubaria triappendiculata Bernard	354		90	68	10		29	39
Ulothrix sp. Kuetz.								

APPENDIX C_{22} (cont.)

PHYTOPLANKTON

(recorded as numbers per ml)

	28 Jul 72				4 Aug 72			
	Pond 1	Pond 2	Pond 3	Pond 4	Pond 1	Pond 2	Pond 3	Pond 4
Chrysophyta:								
Chrysamoeba radians Klebs								
Chrysococcus rufescens Klebs								
Derepyxis sp. Stokes								
Diceras phaseolus Fott					10	19		10
Dinobryon bavaricum Imhof	222	429	451		222	850	1751	772
D. divergens Imhof		23						
D. sertularia Ehrenberg	647	1848	1285	1690	434	415		
Kephyrion ovum Pascher			90	135	29	96	637	521
Mallomonas acaroides var. moskovensis (Wermel) Krieger					19			
M. caudata Iwanoff								
Ochromonas sp. Wystozki								
Ophiocytium bicuspidatum (Borge) Lemm.								
O. capitatum Wolle		23			492	116	20	68
Euglenophyta:								
Euglena acus Ehrenberg					77	19		
E. elastica Prescott	10		158	90	29	38	241	154
E. oxyuris Schmarda								
E. sp. No. 1 (40 - 90 long)			113	113	38	48	154	184
E. sp. No. 2 (90 - 120 long)							20	
Lepocinclis fusiformis (Carter) Lemm.								
L. glabra fa. minor Prescott		23			78	126	96	48
L. sphagnophila Lemm.								
Phacus sp. Dujardin								
P. acuminatus Stokes			23		29	19	38	19
P. longicauda (Ehr.) Dujardin								
P. nordstedtii Lemm.								
P. orbicularis Huebner	45		23		19			19
P. pseudoswirenkoi Prescott								
P. pyrum (Ehr.) Stein								
P. triqueter (Ehr.) Dujardin								
Strombomonas sp. (Skvortzow)								
S. maxima (Skv.)					19	28		10
Trachelomonas sp. Ehr.								
T. charkowiensis Swirenko ex Deflandre								
T. cylindrica Ehr.					10			
T. intermedia Dangeard								
T. lacustris Drezepolski								
T. playfairii Deflandre								
T. robusta Swirenko	32	45	68	45		56	28	38
T. volvocina Ehr.	20	68	113	68	48	96	106	58
Pyrrhophyta:								
Ceratium hirundinella (O. F. Muell.) Dujardin	29	45		23	68	38	20	96
Glenodinium penardiforme (Linde) Schiller								
G. pulvisculus (Ehr.) Stein			90				270	78
G. quadridens (Stein) Schiller								
Cryptophyta:								
Rhodomonas lacustris Pascher & Ruttner	10		68	45	20	77	48	68
Other Flagellates:								
Grey-green; globose to irregular: unequal flagella, often one quite long; similar to small Chlorella; chloroplast not obvious								
Bacillariophyta:								
Achnanthes Bory		45	90	248	78	10	126	
Amphipleura pellucida Kuetz.								
Amphora Ehr.				23		10		
Caloneis Cleve								
Cocconeis Ehr.	45				10			10
Cyclotella Kuetz.	58	270	834	1329	77	116	2215	1824
Cymbella Agardh					28		48	39
Cymbella microcephala Grun.	10		23		20	19	68	
Diploneis Ehr.	10							10

APPENDIX C_{22} (cont.)

PHYTOPLANKTON
(recorded as numbers per ml)

	28 Jul 72				4 Aug 72			
	Pond 1	Pond 2	Pond 3	Pond 4	Pond 1	Pond 2	Pond 3	Pond 4
Bacillariophyta (cont.):								
Epithemia Brebisson								
Eunotia Ehr.						10		10
Fragilaria Lyngbye	39			45	58		106	38
Gomphonema Agardh			23		20	10	76	28
Gyrosigma Hassal		23						
Melosira Agardh								
Navicula Bory	23	23	68	45	58	10	212	48
Neidium Pftz.								
Nitzschia acicularis W. Smith								
Nitzschia Hassall	61	45	180	113	222	126	222	48
Pinnularia Ehr.			23					
Rhizosolenia Ehr.								
Rhopalodia gibba (Ehr.) O. Muell.				23				
Stauroneis Ehr.								
Stephanodiscus Ehr.								
Synedra Ehr.	20	23	90	135	424	125	588	598
* *Additions*								
Chlorophyta:								
Elakatothrix gelatinosa Wille			3434	45				
Oocystis lacustris Chodat		23						
Scenedesmus hystrix Lagerheim							10	

APPENDIX C_{22} (cont.)

PHYTOPLANKTON

(recorded as numbers per ml)

	11 Aug 72				25 Aug 72			
	Pond 1	Pond 2	Pond 3	Pond 4	Pond 1	Pond 2	Pond 3	Pond 4
Cyanophyta:								
Anabaena sp. Bory	10			10		45		55
A. viguieri Denis & Fremy								
* Anabaenopsis elenkinii Miller								
Chroococcus dispersus (Keissl.) Lemm.	29							
* Dactylococcopsis acicularis Lemm.	165			20				
* Lyngbya sp. Agardh								
Merismopedia tenuissima Lemm.	50							
Microcystis aeruginosa Kuetz.								
Oscillatoria sp. Vaucher	299			10	1599	1030	11	576
O. acutissima Kufferath								
O. hamelii Fremy								
O. limnetica Lemmermann	200							
O. subbrevis Schmidle								
O. tenuis var. tergestina (Kuetz.) Rabenhorst								
Rhabdoderma sigmoidea fa. minor Moore & Carter								
Spirulina nordstedtii Gomont		50						11
S. princeps (West & West) G. S. West								
Chlorophyta:								
Acanthosphaera zachariasi Lemm.								
Ankistrodesmus falcatus (Corda) Ralfs	4218	2515	5419	19099	451	180	90	450
A. spiralis (Turner) Lemm.	3671	2193	106	261	270	105	244	162
Characium limneticum Lemm.	29			10			22	112
Chlamydomonas sp. Ehr.		50	550					
Chlorella vulgaris Beyerinck	2646	911	598	2959	3098	1149	10693	3669
Chodatella chodati (Bernard) Ley.	58	29		50	7		22	11
Cladophora sp. Kuetz.								
Closterium sp. Nitzsch	10	68	50	251				
Cosmarium sp. Corda								
Crucigenia quadrata Morren	20			10	19	69		86
C. tetrapedia (Kirch.) West & West	147	890	274	517	1761	2319	1752	2078
Dictyosphaerium pulchellum Wood								
Echinosphaerella limnetica G. M. Smith								
Euastrum Ehr.								
Franceia droescheri (Lemm.) G. M. Smith								
F. ovalis (France) Lemm.	29			10				
F. tuberculata G. M. Smith								
Golenkinia radiata (Chod.) Wille	99		50	295		23	56	124
Green globose colony cf. Coelastrum Naegeli in Kuetz.								
Kirchneriella obesa (W. West) Schmidle					7			
Lagerheimia longiseta (Lemm.) Printz	20							
L. quadriseta (Lemm.) G. M. Smith								22
L. subsala Lemm.								
Mougeotia sp. (C. A. Agardh) Wittrock	10			10				
Oedogonium sp. Link							22	
Oocystis eremosphaeria G. M. Smith								
O. gloeocystiformis Borge								
Pandorina morum (Muell.) Bory		50						
Pediastrum duplex Meyen			20	50				
P. tetras (Ehren.) Ralfs			10	10				
Planktosphaeria gelatinosa G. M. Smith			50	50				
Pleurotaenium Naeg.								
Scenedesmus abundans (Kirch.) Chodat	235	261	345	899	112	113	758	712
S. bijuga (Turp.) Lagerheim	2232	403	367	521	3223	532	344	223
S. dimorphus (Turp.) Kuetz.	189	99		118	23	32	55	143
* S. quadricauda (Turp.) de Brebisson in de Brebisson & Godey	50	10	39	79	23	7	100	11
Scenedesmus sp. (2 spines)	39	10						
Schroederia setigera (Schroed.) Lemm.	200	50	100	100	32	32	64	22
Selenastrum minutum (Naeg.) Collins	428	777	430	650	338	113	1331	965
Spondylosium sp. de Brebisson								
* Sorastrum americanum (Bohlin) Schmidle			60				32	
Tetradesmus Wisconsinense G. M. Smith								
Tetraedron duospinum Ackley								
T. minimum (A. Braun) Hansgirg	68	189	199	49	23	70	68	22
T. regulare Kuetz.	89	10	77			23		56
T. trigonum (Naeg.) Hansgirg		50			7	29	22	11
Tetrastrum staurogeniaeforme (Schroeder) Lemm.								
Treubaria triappendiculata Bernard	120						22	34
Ulothrix sp. Kuetz.								

APPENDIX C_{22} (cont.)

PHYTOPLANKTON

(recorded as numbers per ml)

	11 Aug 72				25 Aug 72			
	Pond 1	Pond 2	Pond 3	Pond 4	Pond 1	Pond 2	Pond 3	Pond 4
Chrysophyta:								
Chrysamoeba radians Klebs								
Chrysococcus rufescens Klebs	1450	1050	650	250		157	42	32
Derepyxis sp. Stokes								
Diceras phaseolus Fott	10	20	10					
Dinobryon bavaricum Imhof	68		408	282		23	811	1757
D. *divergens* Imhof							676	518
D. *settularia* Ehrenberg	100	200			391	746	22	22
Kephyrion ovum Pascher	249	210	1222	782	48	23		
Mallomonas acaroides var. *moskovensis* (Wermel) Krieger	50	100					22	
M. caudata Iwanoff				50			32	
Ochromonas sp. Wystozki							255	
Ophiocytium bicuspidatum (Borge) Lemm.								
O. capitatum Wolle	261	222	116	290	90		45	168
*								
Euglenophyta:								
Euglena acus Ehrenberg	10	50	70	200			44	145
* *E. elastica* Prescott	10	110	58	306	7	29		112
E. oxyuris Schmarda							44	
E. sp. No. 1 (40 - 90 long)		39	338	77	23	74	90	248
E. sp. No. 2 (90 - 120 long)			20					
Lepocinclis fusiformis (Carter) Lemm.			49					
L. glabra fa. *minor* Prescott	77	10	77	120	178	318	22	246
L. sphagnophila Lemm.							22	
Phacus sp. Dujardin		10						
* *P. acuminatus* Stokes			20	10	68	23	158	112
P. longicauda (Ehr.) Dujardin					7	63		22
P. nordstedtii Lemm.		50						
P. orbicularis Huebner		200	108		85	13		22
P. pseudoswirenkoi Prescott						7		
P. pyrum (Ehr.) Stein								
P. triqueter (Ehr.) Dujardin						44		
Strombomonas sp. (Skvortzow)		29						
S. maxima (Skv.)		20		10	77	177		
* *Trachelomonas sp.* Ehr.		150						
T. charkowiensis Swirenko ex Deflandre								
T. cylindrica Ehr.								
T. intermedia Dangeard								
T. lacustris Drezepolski								
T. playfairii Deflandre								
T. robusta Swirenko		77	20			68	22	
T. volvocina Ehr.	20	247	168	210	69	23	68	248
Pyrrhophyta:								
Ceratium hirundinella (O. F. Muell.) Dujardin	10	50	20			54		
Glenodinium penardiforme (Linde) Schiller								
G. pulvisculus (Ehr.) Stein			184	276	7	7	119	90
G. quadridens (Stein) Schiller		20	639	632	68	23	510	364
Cryptophyta:								
Rhodomonas lacustris Pascher & Ruttner	110	249	120	120	115	68	85	54
Other Flagellates:								
Grey-green; globose to irregular; unequal flagella, often one quite long; similar to small *Chlorella*; chloroplast not obvious								
Bacillariophyta:								
Achnanthes Bory	250	250	339	589	99		90	
Amphipleura pellucida Kuetz.					7			
Amphora Ehr.		179			52	54	22	22
Caloneis Cleve	213	29		60			22	
Cocconeis Ehr.								
Cyclotella Kuetz.	118	58	475	328	676	518	224	146
Cymbella Agardh	50	50	20	70	7			54
* Cymbella *microcephala* Grun.	100	50					22	
Diploneis Ehr.	10							

APPENDIX C_{22} (cont.)

PHYTOPLANKTON
(recorded as numbers per ml)

	11 Aug 72				25 Aug 72			
	Pond 1	Pond 2	Pond 3	Pond 4	Pond 1	Pond 2	Pond 3	Pond 4
Bacillariophyta (cont.):								
Epithemia Brebisson								
Eunotia Ehr.	68	10						
Fragilaria Lyngbye			300	60		25		
Gomphonema Agardh			110	29	23	23		56
Gyrosigma Hassal					7			
Melosira Agardh								
Navicula Bory	110	389	299	200	400	63	135	
Neidium Pftz.								
Nitzschia acicularis W. Smith		63						
Nitzschia Hassall	405	79	177	70	217	102	336	45
Pinnularia Ehr.								
Rhizosolenia Ehr.								
Rhopalodia gibba (Ehr.) O. Muell.				50				
Stauroneis Ehr.								
Stephanodiscus Ehr.					25			
Synedra Ehr.	583	702	164	419	1132	911	141	184
*** Additions**								
Cyanophyta:								
Aphanothece stagnina (Spreng.) A. Braun in Rab.					23			
Dactylococcopsis fascicularis Lemm.	1250	1450	100	50				
Merismopedia glauca (Ehr.) Naegeli		29						
Chlorophyta:								
Scenedesmus opoliensis P. Richter	50							
Staurastrum sp. Meyen			10					
Chrysophyta:								
Ophiocytium elongatum West & West				50				
Euglenophyta:								
Euglena gracilis Klebs			145					
Phacus curuicauda		10						
Trachelomonas bulla (Stein) Deflandre				50				
Bacillariophyta:								
Diatoma sp. DeCandolle				19				

APPENDIX C_{22} (cont.)

PHYTOPLANKTON

(recorded as numbers per ml)

	14 Sep 72				21 Sep 72			
	Pond 1	Pond 2	Pond 3	Pond 4	Pond 1	Pond 2	Pond 3	Pond 4
Cyanophyta:								
Anabaena sp. Bory		19		19		10	44	618
A. viguieri Denis & Fremy							29	
Anabaenopsis elenkinii Miller			58	341			275	386
Chroococcus dispersus (Keissl.) Lemm.								
Dactylococcopsis acicularis Lemm.								
Lyngbya sp. Agardh								
Merismopedia tenuissima Lemm.								
Microcystis aeruginosa Kuetz.					10			
Oscillatoria sp. Vaucher			23	68			10	10
O. acutissima Kufferath								
O. hamelii Fremy								
O. limnetica Lemmermann								
O. subbrevis Schmidle								
O. tenuis var. tergestina (Kuetz.) Rabenhorst								
Rhabdoderma sigmoidea fa. minor Moore & Carter		23	10				29	39
Spirulina nordstedtii Gomont	20	10						
S. princeps (West & West) G. S. West								
Chlorophyta:								
Acanthosphaera zachariasi Lemm.	49		23	23	10	10	58	39
Ankistrodesmus falcatus (Corda) Ralfs	89	20	113	42	58	29	20	77
A. spiralis (Turner) Lemm.	280	531	52	58	2480	2507	217	367
Characium limneticum Lemm.	60	23		90				10
Chlamydomonas sp. Ehr.								
Chlorella vulgaris Beyerinck	847	977	3214	3509	1906	1110	2889	3642
Chodatella chodati (Bernard) Ley.			23	23	20			
Cladophora sp. Kuetz.								20
Closterium sp. Nitzsch								
Cosmarium sp. Corda								
Crucigenia quadrata Morren	20	48		58				
C. tetrapedia (Kirch.) West & West	159	303	859	1110	463	386	1722	1909
Dictyosphaerium pulchellum Wood					10			
Echinosphaerella limnetica G. M. Smith								
Euastrum Ehr.								
Franceia droescheri (Lemm.) G. M. Smith								
F. ovalis (France) Lemm.								
F. tuberculata G. M. Smith								
Golenkinia radiata (Chod.) Wille	10	52	23	7	58	29	87	87
Green globose colony cf. Coelastrum Naegeli in Kuetz.							78	87
Kirchneriella obesa (W. West) Schmidle					39	10	29	20
Lagerheimia longiseta (Lemm.) Printz				10		10		77
L. quadriseta (Lemm.) G. M. Smith								
L. subsala Lemm.								
Mougeotia sp. (C. A. Agardh) Wittrock								
Oedogonium sp. Link							10	10
Oocystis eremosphaeria G. M. Smith								
O. gloeocystiformis Borge								
Pandorina morum (Muell.) Bory								
Pediastrum duplex Meyen					10	29		
P. tetras (Ehren.) Ralfs								
Planktosphaeria gelatinosa G. M. Smith		10						
Pleurotaenium Naeg.								
Scenedesmus abundans (Kirch.) Chodat	510	312	180	319	97	87	261	347
S. bijuga (Turp.) Lagerheim	177	151	441	338	435	116	1249	1052
S. dimorphus (Turp.) Kuetz.				61	10	49	53	77
S. quadricauda (Turp.) de Brebisson in de Brebisson & Godey	20	58	23	10	10	19	189	48
Scenedesmus sp. (2 spines)	30	158			49	126		29
Schroederia setigera (Schroed.) Lemm.								
Selenastrum minutum (Naeg.) Collins	180	138	351	779	406	251	689	473
Spondylosium sp. de Brebisson								
Sorastrum americanum (Bohlin) Schmidle								
Tetradesmus Wisconsinense G. M. Smith						10		
Tetraedron duospinum Ackley								
T. minimum (A. Braun) Hansgirg		10	10	23			10	10
T. regulare Kuetz.							29	10
T. trigonum (Naeg.) Hansgirg		23						
Tetrastrum staurogeniaeforme (Schroeder) Lemm.								
Treubaria triappendiculata Bernard								
Ulothrix sp. Kuetz.								

PHYTOPLANKTON
(recorded as numbers per ml)

	14 Sep 72				21 Sep 72			
	Pond 1	Pond 2	Pond 3	Pond 4	Pond 1	Pond 2	Pond 3	Pond 4
Chrysophyta:								
Chrysamoeba radians Klebs			10					
Chrysococcus rufescens Klebs				29				
Derepyxis sp. Stokes		23		68				
Diceras phaseolus Fott	69	71				10		
Dinobryon bavaricum Imhof						135	4868	6935
D. divergens Imhof								
D. sertularia Ehrenberg						10		
Kephyrion ovum Pascher								
Mallomonas acaroides var. moskovensis (Wermel) Krieger	39	77	39	19	39	20		
M. caudata Iwanoff		10						20
Ochromonas sp. Wystozki					125			
Ophiocytium bicuspidatum (Borge) Lemm.								
O. capitatum Wolle		64		23	87		20	39
Euglenophyta:								
Euglena acus Ehrenberg	10		52	68	29		58	48
E. elastica Prescott			164	23	20	10	125	87
E. oxyuris Schmarda			10	58				10
E. sp. No. 1 (40 - 90 long)	30		45	23	10	10	193	20
E. sp. No. 2 (90 - 120 long)					10	20	10	
Lepocinclis fusiformis (Carter) Lemm.								
L. glabra fa. minor Prescott						10		
L. sphagnophila Lemm.								
Phacus sp. Dujardin								
P. acuminatus Stokes					48	48	48	20
P. longicauda (Ehr.) Dujardin			23				14	
P. nordstedtii Lemm.								
P. orbicularis Huebner	20	23	74		10	20	101	10
P. pseudoswirenkoi Prescott								
P. pyrum (Ehr.) Stein								
P. triqueter (Ehr.) Dujardin								
Strombomonas sp. (Skvortzow)								
S. maxima (Skv.)	49	177			39	145		
Trachelomonas sp. Ehr.								
T. charkowiensis Swirenko ex Deflandre								
T. cylindrica Ehr.								
T. intermedia Dangeard								
T. lacustris Drezepolski					39			
T. playfairii Deflandre								
T. robusta Swirenko	30	45			20	39		
T. volvocina Ehr.	49	68	151	315	19	29	483	676
Pyrrhophyta:								
Ceratium hirundinella (O. F. Muell.) Dujardin					20	10	24	10
Glenodinium penardiforme (Linde) Schiller								
G. pulvisculus (Ehr.) Stein							20	58
G. quadridens (Stein) Schiller					29	68	280	97
Cryptophyta:								
Rhodomonas lacustris Pascher & Ruttner	261	58	71	196	203	454	125	58
Other Flagellates:								
Grey-green; globose to irregular: unequal flagella, often one quite long; similar to small Chlorella; chloroplast not obvious					20	251		
Bacillariophyta:								
Achnanthes Bory		23			77	10	48	19
Amphipleura pellucida Kuetz.								
Amphora Ehr.						20		19
Caloneis Cleve								
Cocconeis Ehr.	30	10		23			19	
Cyclotella Kuetz.	489	212	174	87	405	261	87	77
Cymbella Agardh					29			
Cymbella microcephala Grun.			10					29
Diploneis Ehr.	30							

APPENDIX C_{22} (cont.)

PHYTOPLANKTON
(recorded as numbers per ml)

	14 Sep 72				21 Sep 72			
	Pond 1	Pond 2	Pond 3	Pond 4	Pond 1	Pond 2	Pond 3	Pond 4
Bacillariophyta (cont.):								
Epithemia Brebisson				23				
Eunotia Ehr.								
Fragilaria Lyngbye					20		10	
Gomphonema Agardh					10	87	43	10
Gyrosigma Hassal								10
Melosira Agardh								
Navicula Bory	68	23	42		164	39	92	48
Neidium Pftz.								
Nitzschia acicularis W. Smith								
Nitzschia Hassall		23	23	32	39	48	45	20
Pinnularia Ehr.								
Rhizosolenia Ehr.	20	10			39	77	10	
Rhopalodia gibba (Ehr.) O. Muell.						10		
Stauroneis Ehr.						10		
Stephanodiscus Ehr.					20		39	
Synedra Ehr.	237	286	21166	3790	1409	347	47892	17099

APPENDIX C_{22} (cont.)

PHYTOPLANKTON

(recorded as numbers per ml)

	2 Oct 72				6 Oct 72			
	Pond 1	Pond 2	Pond 3	Pond 4	Pond 1	Pond 2	Pond 3	Pond 4
Cyanophyta:								
Anabaena sp. Bory			95	323			29	105
A. viguieri Denis & Fremy								
Anabaenopsis elenkinii Miller			219	323			38	209
Chroococcus dispersus (Keissl.) Lemm.								
Dactylococcopsis acicularis Lemm.								
Lyngbya sp. Agardh								
Merismopedia tenuissima Lemm.								
Microcystis aeruginosa Kuetz.					19		10	
Oscillatoria sp. Vaucher			10					
O. acutissima Kufferath								
O. hamelii Fremy								
O. limnetica Lemmermann								
O. subbrevis Schmidle								
O. tenuis var. tergestina (Kuetz.) Rabenhorst								
Rhabdoderma sigmoidea fa. minor Moore & Carter								
Spirulina nordstedtii Gomont		10						
S. princeps (West & West) G. S. West								
Chlorophyta:								
Acanthosphaera zachariasi Lemm.	29	10	19			38		19
Ankistrodesmus falcatus (Corda) Ralfs	67	10	190	86	48		105	76
A. spiralis (Turner) Lemm.	1912	1064	352	532	1178	1083	228	314
Characium limneticum Lemm.	19		19	10				
Chlamydomonas sp. Ehr.								
Chlorella vulgaris Beyerinck	1397	333	5779	5823	2679	798	5198	6843
Chodatella chodati (Bernard) Ley.				10				
Cladophora sp. Kuetz.				19				
Closterium sp. Nitzsch								
Cosmarium sp. Corda			10					
Crucigenia quadrata Morren				38				
C. tetrapedia (Kirch.) West & West	333	76	1178	1597	162	276	485	760
Dictyosphaerium pulchellum Wood								
Echinosphaerella limnetica G. M. Smith								
Euastrum Ehr.								
Franceia droescheri (Lemm.) G. M. Smith								
F. ovalis (France) Lemm.								
F. tuberculata G. M. Smith								
Golenkinia radiata (Chod.) Wille	38	29	19	48	19		57	10
Green globose colony cf. Coelastrum Naegeli in Kuetz.		57			10	38		
Kirchneriella obesa (W. West) Schmidle	86	19	10	19	29		10	
Lagerheimia longiseta (Lemm.) Printz			19				10	
L. quadriseta (Lemm.) G. M. Smith			10					29
L. subsala Lemm.								
Mougeotia sp. (C. A. Agardh) Wittrock								
Oedogonium sp. Link								
Oocystis eremosphaeria G. M. Smith								
O. gloeocystiformis Borge								
Pandorina morum (Muell.) Bory								
Pediastrum duplex Meyen					10			10
P. tetras (Ehren.) Ralfs								
Planktosphaeria gelatinosa G. M. Smith								
Pleurotaenium Naeg.								
Scenedesmus abundans (Kirch.) Chodat	105	38	399	399	48	86	152	209
S. bijuga (Turp.) Lagerheim	228	57	551	694	143	67	409	456
S. dimorphus (Turp.) Kuetz.	29	19	29	143	10	19		67
S. quadricauda (Turp.) de Brebisson in de Brebisson & Godey	19		57	57	19		57	48
Scenedesmus sp. (2 spines)		10	19			19	10	
Schroederia setigera (Schroed.) Lemm.								
Selenastrum minutum (Naeg.) Collins	475	656	409	399	561	1131	152	105
Spondylosium sp. de Brebisson								
Sorastrum americanum (Bohlin) Schmidle								
Tetradesmus Wisconsinense G. M. Smith								
Tetraedron duospinum Ackley								
T. minimum (A. Braun) Hansgirg						10		10
T. regulare Kuetz.				10				
T. trigonum (Naeg.) Hansgirg			10					
Tetrastrum staurogeniaeforme (Schroeder) Lemm.								
Treubaria triappendiculata Bernard								
Ulothrix sp. Kuetz.						10		

APPENDIX C$_{22}$ (cont.)

PHYTOPLANKTON

(recorded as numbers per ml)

	2 Oct 72				6 Oct 72			
	Pond 1	Pond 2	Pond 3	Pond 4	Pond 1	Pond 2	Pond 3	Pond 4
Chrysophyta:								
Chrysamoeba radians Klebs								
Chrysococcus rufescens Klebs								
Derepyxis sp. Stokes								
Diceras phaseolus Fott								
Dinobryon bavaricum Imhof	922	551	4260	1343	1159	551	2320	1074
D. divergens Imhof								
D. sertularia Ehrenberg								
Kephyrion ovum Pascher			10		10			
Mallomonas acaroides var. moskovensis (Wermel) Krieger	19				19	19		
M. caudata Iwanoff								
Ochromonas sp. Wystozki								
Ophiocytium bicuspidatum (Borge) Lemm.								
O. capitatum Wolle	48	48	67	38	10	19	38	38
Euglenophyta:								
Euglena acus Ehrenberg	10		29	38	19	19	48	10
E. elastica Prescott			10	38	10	29	48	124
E. oxyuris Schmarda								
E. sp. No. 1 (40 - 90 long)	38		67	200	19	10	10	124
E. sp. No. 2 (90 - 120 long)				29	19			19
Lepocinclis fusiformis (Carter) Lemm.								
L. glabra fa. minor Prescott								
L. sphagnophila Lemm.								
Phacus sp. Dujardin								
P. acuminatus Stokes		10	10	19	10			19
P. longicauda (Ehr.) Dujardin					10			
P. nordstedtii Lemm.								
P. orbicularis Huebner		10	57				67	19
P. pseudoswirenkoi Prescott								
P. pyrum (Ehr.) Stein								
P. triqueter (Ehr.) Dujardin								
Strombomonas sp. (Skvortzow)								
S. maxima (Skv.)		19				99		
Trachelomonas sp. Ehr.			10					
T. charkowiensis Swirenko ex Deflandre								
T. cylindrica Ehr.								
T. intermedia Dangeard								
T. lacustris Drezepolski								
T. playfairii Deflandre			10					
T. robusta Swirenko	10	19	10	19				
T. volvocina Ehr.			532	143		10	48	19
Pyrrhophyta:								
Ceratium hirundinella (O. F. Muell.) Dujardin	19	10				10		
Glenodinium penardiforme (Linde) Schiller								
G. pulvisculus (Ehr.) Stein			29	29	10		29	38
G. quadridens (Stein) Schiller	10	105	29	523		10	10	48
Cryptophyta:								
Rhodomonas lacustris Pascher & Ruttner	105							
Other Flagellates:								
Grey-green; globose to irregular: unequal flagella, often one quite long, similar to small Chlorella; chloroplast not obvious					67		10	10
Bacillariophyta:								
Achnanthes Bory	10	29	29	10	10	19	19	
Amphipleura pellucida Kuetz.						10		
Amphora Ehr.	10		57	19	10	19		
Caloneis Cleve			10					
Cocconeis Ehr.						10		19
Cyclotella Kuetz.	124	124	48	29	105	133	114	10
Cymbella Agardh		10					10	
Cymbella microcephala Grun.		19	10				10	10
Diploneis Ehr.			29		10			

APPENDIX C_{22} (cont.)

PHYTOPLANKTON
(recorded as numbers per ml)

	2 Oct 72				6 Oct 72			
	Pond 1	Pond 2	Pond 3	Pond 4	Pond 1	Pond 2	Pond 3	Pond 4
Bacillariophyta (cont.):								
Epithemia Brebisson								
Eunotia Ehr.								10
Fragilaria Lyngbye	38		29			19		
Gomphonema Agardh		10	48	10	10	10		10
Gyrosigma Hassal				10				
Melosira Agardh								
Navicula Bory	95	76	76	76	29	76		29
Neidium Pftz.					10			
Nitzschia acicularis W. Smith	38		19		19	29	10	
Nitzschia Hassall	114	57			114	133	19	10
Pinnularia Ehr.								
Rhizosolenia Ehr.	86	10	19		29		10	
Rhopalodia gibba (Ehr.) O. Muell.								
Stauroneis Ehr.								
Stephanodiscus Ehr.	19							
Synedra Ehr.	209	105	5843	27898	209	266	2062	9354

APPENDIX C_{22} (cont.)

PHYTOPLANKTON

(recorded as numbers per ml)

	17 Oct 72				24 Oct 72			
	Pond 1	Pond 2	Pond 3	Pond 4	Pond 1	Pond 2	Pond 3	Pond 4
Cyanophyta:								
Anabaena sp. Bory			10	29				29
A. viguieri Denis & Fremy								
Anabaenopsis elenkinii Miller			20	87			68	10
Chroococcus dispersus (Keissl.) Lemm.								
Dactylococcopsis acicularis Lemm.							10	
Lyngbya sp. Agardh								
Merismopedia tenuissima Lemm.								
Microcystis aeruginosa Kuetz.	10						20	
Oscillatoria sp. Vaucher	10			10				
O. acutissima Kufferath								
O. hamelii Fremy								
O. limnetica Lemmermann				10				
O. subbrevis Schmidle								
O. tenuis var. tergestina (Kuetz.) Rabenhorst								
Rhabdoderma sigmoidea fa. minor Moore & Carter								
Spirulina nordstedtii Gomont								
S. princeps (West & West) G. S. West								
Chlorophyta:								
Acanthosphaera zachariasi Lemm.	116	39	10		20			
Ankistrodesmus falcatus (Corda) Ralfs	77	87	154	39	29	193	97	48
A. spiralis (Turner) Lemm.	2741	2283	405	386	2403	1380	174	145
Characium limneticum Lemm.								10
Chlamydomonas sp. Ehr.			19	19				
Chlorella vulgaris Beyerinck	2248	3841	5551	6285	2162	1906	3158	6705
Chodatella chodati (Bernard) Ley.							10	
Cladophora sp. Kuetz.								
Closterium sp. Nitzsch								
Cosmarium sp. Corda								
Crucigenia quadrata Morren					29			
C. tetrapedia (Kirch.) West & West	444	1119	222	318	637	1187	203	193
Dictyosphaerium pulchellum Wood								
Echinosphaerella limnetica G. M. Smith								
Euastrum Ehr.								
Franceia droescheri (Lemm.) G. M. Smith								
F. ovalis (France) Lemm.								
F. tuberculata G. M. Smith								
Golenkinia radiata (Chod.) Wille	116	10	48	87	39	10	10	19
Green globose colony cf. Coelastrum Naegeli in Kuetz.	10			10		19	10	
Kirchneriella obesa (W. West) Schmidle	77	58	48	10	39		10	
Lagerheimia longiseta (Lemm.) Printz				19			19	
L. quadriseta (Lemm.) G. M. Smith				77		10	39	68
L. subsala Lemm.								66
Mougeotia sp. (C. A. Agardh) Wittrock								10
Oedogonium sp. Link								
Oocystis eremosphaeria G. M. Smith								
O. gloeocystiformis Borge								
Pandorina morum (Muell.) Bory								
Pediastrum duplex Meyen	10							
P. tetras (Ehren.) Ralfs								
Planktosphaeria gelatinosa G. M. Smith							10	
Pleurotaenium Naeg.								
Scenedesmus abundans (Kirch.) Chodat	386	309	434	550	280	154	376	280
S. bijuga (Turp.) Lagerheim	425	309	261	174	154	135	145	87
S. dimorphus (Turp.) Kuetz.	77	29	19	87	29	19	19	68
S. quadricauda (Turp.) de Brebisson in de Brebisson & Godey	48	10	96	48	19	19	48	48
Scenedesmus sp. (2 spines)	77	58			29	39		
Schroederia setigera (Schroed.) Lemm.							10	19
Selenastrum minutum (Naeg.) Collins	907	5424	232	154	1004	4247	222	87
Spondylosium sp. de Brebisson								
Sorastrum americanum (Bohlin) Schmidle								
Tetradesmus Wisconsinense G. M. Smith								
Tetraedron duospinum Ackley								
T. minimum (A. Braun) Hansgirg		10	10		19			
T. regulare Kuetz.					19			
T. trigonum (Naeg.) Hansgirg		10				10		
Tetrastrum staurogeniaeforme (Schroeder) Lemm.								
Treubaria triappendiculata Bernard								
Ulothrix sp. Kuetz.								

PHYTOPLANKTON

(recorded as numbers per ml)

	17 Oct 72				24 Oct 72			
	Pond 1	Pond 2	Pond 3	Pond 4	Pond 1	Pond 2	Pond 3	Pond 4
Chrysophyta:								
Chrysamoeba radians Klebs								
Chrysococcus rufescens Klebs								
Derepyxis sp. Stokes								
Diceras phaseolus Fott								
Dinobryon bavaricum Imhof	926	811	125	396	425	849	29	58
D. divergens Imhof								
D. sertularia Ehrenberg								
Kephyrion ovum Pascher								
Mallomonas acaroides var. moskovensis (Wermel) Krieger	10							
M. caudata Iwanoff								
Ochromonas sp. Wystozki								
Ophiocytium bicuspidatum (Borge) Lemm.								
O. capitatum Wolle	10	10	97	29		10	10	10
Euglenophyta:								
Euglena acus Ehrenberg	19		58	10	125	19	39	
E. elastica Prescott	19	10		29			19	
E. oxyuris Schmarda								
E. sp. No. 1 (40 - 90 long)	10		68	77	19	10	29	
E. sp. No. 2 (90 - 120 long)		10		19			10	10
Lepocinclis fusiformis (Carter) Lemm.								
L. glabra fa. minor Prescott								
L. sphagnophila Lemm.								
Phacus sp. Dujardin				10				
P. acuminatus Stokes	10		10					
P. longicauda (Ehr.) Dujardin								
P. nordstedtii Lemm.		10						
P. orbicularis Huebner			10				10	
P. pseudoswirenkoi Prescott								
P. pyrum (Ehr.) Stein								
P. triqueter (Ehr.) Dujardin								
Strombomonas sp. (Skvortzow)								
S. maxima (Skv.)								
Trachelomonas sp. Ehr.								
T. charkowiensis Swirenko ex Deflandre								
T. cylindrica Ehr.								
T. intermedia Dangeard				10				
T. lacustris Drezepolski								
T. playfairii Deflandre								
T. robusta Swirenko								
T. volvocina Ehr.			97	135	10		68	39
Pyrrhophyta:								
Ceratium hirundinella (O. F. Muell.) Dujardin								
Glenodinium penardiforme (Linde) Schiller								
G. pulvisculus (Ehr.) Stein			39	19	19		116	10
G. quadridens (Stein) Schiller								
Cryptophyta:								
Rhodomonas lacustris Pascher & Ruttner			29	48	10	164	318	251
Other Flagellates:								
Grey-green, globose to irregular: unequal flagella, often one quite long; similar to small Chlorella; chloroplast not obvious								
Bacillariophyta:								
Achnanthes Bory	68	19	19	29			29	19
Amphipleura pellucida Kuetz.								
Amphora Ehr.	10	10	29	10	10			
Caloneis Cleve								
Cocconeis Ehr.		10	29	19				
Cyclotella Kuetz.	222	116	154	145	280	68	212	19
Cymbella Agardh	10	10	29	19			29	
Cymbella microcephala Grun.		19		10		10	10	10
Diploneis Ehr.					10	10		

PHYTOPLANKTON
(recorded as numbers per ml)

	17 Oct 72				24 Oct 72			
	Pond 1	Pond 2	Pond 3	Pond 4	Pond 1	Pond 2	Pond 3	Pond 4
Bacillariophyta (cont.):								
Epithemia Brebisson		10						
Eunotia Ehr.				19		48	96	29
*Fragilaria Lyngbye	10		39	39		10		
Gomphonema Agardh	10						10	
Gyrosigma Hassal				66				
Melosira Agardh	87	87	145	87	10	39	77	58
Navicula Bory								
Neidium Pfitz.	48	212	10			29	29	19
Nitzschia acicularis W. Smith	29	68	48	68	58		29	19
Nitzschia Hassall							10	
Pinnularia Ehr.			10					
Rhizosolenia Ehr.								
Rhopalodia gibba (Ehr.) O. Muell.								
Stauroneis Ehr.	10							
Stephanodiscus Ehr.	357	695	579	6128	193	473	1216	695
Synedra Ehr.								

* Additions

Euglenophyta:

	17 Oct 72				24 Oct 72			
	Pond 1	Pond 2	Pond 3	Pond 4	Pond 1	Pond 2	Pond 3	Pond 4
Trachelomonas abrupta (Swir.) Deflandre				10				

APPENDIX C_{22} (cont.)

PHYTOPLANKTON

(recorded as numbers per ml)

	25 Apr 73				14 May 73			
	Pond 1	Pond 2	Pond 3	Pond 4	Pond 1	Pond 2	Pond 3	Pond 4
Cyanophyta:								
Anabaena sp. Bory								
A. viguieri Denis & Fremy								
Anabaenopsis elenkinii Miller								
Chroococcus dispersus (Keissl.) Lemm.								
Dactylococcopsis acicularis Lemm.								
Lyngbya sp. Agardh								
Merismopedia tenuissima Lemm.								
Microcystis aeruginosa Kuetz.							45	
Oscillatoria sp. Vaucher	45					45	811	1487
O. acutissima Kufferath								
O. hamelii Fremy								
O. limnetica Lemmermann								
O. subbrevis Schmidle								
O. tenuis var. tergestina (Kuetz.) Rabenhorst								
Rhabdoderma sigmoidea fa. minor Moore & Carter						45		
Spirulina nordstedtii Gomont								
S. princeps (West & West) G. S. West								
Chlorophyta:								
Acanthosphaera zachariasi Lemm.			45		45			135
Ankistrodesmus falcatus (Corda) Ralfs	586	586	270	270	451	1892	360	856
A. spiralis (Turner) Lemm.			45		45		946	721
Characium limneticum Lemm.						45		45
Chlamydomonas sp. Ehr.								
Chlorella vulgaris Beyerinck	766	676	8290	3064	901	1307	946	2748
Chodatella chodati (Bernard) Ley.								
Cladophora sp. Kuetz.								
Closterium sp. Nitzsch								
Cosmarium sp. Corda								
Crucigenia quadrata Morren								
C. tetrapedia (Kirch.) West & West	315	180	180	315	541	315	135	135
Dictyosphaerium pulchellum Wood								
Echinosphaerella limnetica G. M. Smith			90	90				
Euastrum Ehr.								
Franceia droescheri (Lemm.) G. M. Smith								
F. ovalis (France) Lemm.								
F. tuberculata G. M. Smith								
Golenkinia radiata (Chod.) Wille				90	90			
Green globose colony cf. Coelastrum Naegeli in Kuetz.								
Kirchneriella obesa (W. West) Schmidle					90	45		45
Lagerheimia longiseta (Lemm.) Printz							45	
L. quadriseta (Lemm.) G. M. Smith			45					
L. subsala Lemm.								
Mougeotia sp. (C. A. Agardh) Wittrock								
Oedogonium sp. Link								
Oocystis eremosphaeria G. M. Smith								
O. gloeocystiformis Borge								
Pandorina morum (Muell.) Bory								
Pediastrum duplex Meyen							45	
P. tetras (Ehren.) Ralfs								
Planktosphaeria gelatinosa G. M. Smith								
Pleurotaenium Naeg.								
Scenedesmus abundans (Kirch.) Chodat	180	135	45	45	270	721	451	991
S. bijuga (Turp.) Lagerheim	90	90	45		315	45	45	45
S. dimorphus (Turp.) Kuetz.								
S. quadricauda (Turp.) de Brebisson in de Brebisson & Godey	180	45	45	45	135		45	45
Scenedesmus sp. (2 spines)	90				721	676		
Schroederia setigera (Schroed.) Lemm.								
Selenastrum minutum (Naeg.) Collins	541	541	405	90	451	631	315	45
Spondylosium sp. de Brebisson								
Sorastrum americanum (Bohlin) Schmidle								
Tetradesmus Wisconsinense G. M. Smith								
Tetraedron duospinum Ackley								
T. minimum (A. Braun) Hansgirg					45			45
T. regulare Kuetz.								
T. trigonum (Naeg.) Hansgirg								45
Tetrastrum staurogeniaeforme (Schroeder) Lemm.								
Treubaria triappendiculata Bernard			406	1622				45
Ulothrix sp. Kuetz.								

APPENDIX C_{22} (cont.)

PHYTOPLANKTON
(recorded as numbers per ml)

	25 Apr 73				14 May 73			
	Pond 1	Pond 2	Pond 3	Pond 4	Pond 1	Pond 2	Pond 3	Pond 4
Chrysophyta:								
Chrysamoeba radians Klebs								
Chrysococcus rufescens Klebs								
Derepyxis sp. Stokes								
Diceras phaseolus Fott								
Dinobryon bavaricum Imhof								
D. divergens Imhof								
D. sertularia Ehrenberg	5046	1397	811	225	45		2839	8245
Kephyrion ovum Pascher		45			90		45	180
Mallomonas acaroides var. moskovensis (Wermel) Krieger								
M. caudata Iwanoff								
Ochromonas sp. Wystozki								
Ophiocytium bicuspidatum (Borge) Lemm.								
O. capitatum Wolle			90			90	135	90
Euglenophyta:								
Euglena acus Ehrenberg	45							
E. elastica Prescott								
E. oxyuris Schmarda								
E. sp. No. 1 (40 - 90 long)				90	45			
E. sp. No. 2 (90 - 120 long)								
Lepocinclis fusiformis (Carter) Lemm.								
L. glabra fa. minor Prescott								
L. sphagnophila Lemm.								
Phacus sp. Dujardin								
P. acuminatus Stokes								
P. longicauda (Ehr.) Dujardin								
P. nordstedtii Lemm.								
P. orbicularis Huebner								
P. pseudoswirenkoi Prescott								
P. pyrum (Ehr.) Stein								
P. triqueter (Ehr.) Dujardin								
Strombomonas sp. (Skvortzow)								
S. maxima (Skv.)								
Trachelomonas sp. Ehr.								
T. charkowiensis Swirenko ex Deflandre								
T. cylindrica Ehr.								
T. intermedia Dangeard								
T. lacustris Drezepolski								
T. playfairii Deflandre								
T. robusta Swirenko	45						586	135
T. volvocina Ehr.	45	631		135		45		
Pyrrhophyta:								
Ceratium hirundinella (O. F. Muell.) Dujardin								
Glenodinium penardiforme (Linde) Schiller								
G. pulvisculus (Ehr.) Stein		45		90	90	135		
G. quadridens (Stein) Schiller								
Cryptophyta:								
Rhodomonas lacustris Pascher & Ruttner	135	135	90	496		45	676	811
Other Flagellates:								
Grey-green; globose to irregular: unequal flagella, often one quite long: similar to small Chlorella; chloroplast not obvious								
Bacillariophyta:								
Achnanthes Bory	90	315					180	45
Amphipleura pellucida Kuetz.								
Amphora Ehr.	45			45				
Caloneis Cleve								
Cocconeis Ehr.								
Cyclotella Kuetz.	496	406	3650	4731	924	541	766	1532
Cymbella Agardh						45		45
Cymbella microcephala Grun.								
Diploneis Ehr.					45			

APPENDIX C_{22} (cont.)

PHYTOPLANKTON

(recorded as numbers per ml)

	25 Apr 73				14 May 73			
	Pond 1	Pond 2	Pond 3	Pond 4	Pond 1	Pond 2	Pond 3	Pond 4
Bacillariophyta (cont.):								
Epithemia Brebisson								
Eunotia Ehr.								
Fragilaria Lyngbye								
Gomphonema Agardh	45					90		
Gyrosigma Hassal								
Melosira Agardh								
Navicula Bory	90		135	315	90	135	225	270
Neidium Pftz.								
Nitzschia acicularis W. Smith								
Nitzschia Hassall	180	90	496	496	45	180	270	270
Pinnularia Ehr.						45		
Rhizosolenia Ehr.								
Rhopalodia gibba (Ehr.) O. Muell.								
Stauroneis Ehr.								
Stephanodiscus Ehr.					338			
Synedra Ehr.	2838	2388	5001	11849			991	946
* Additions								
Chlorophyta:								
Elakatothrix gelatinosa Wille					45			
Chrysophyta:								
Chrysopyxis sp. Stein							45	

APPENDIX C_{22} (cont.)

PHYTOPLANKTON

(recorded as numbers per ml)

	21 May 73				29 May 73			
	Pond 1	Pond 2	Pond 3	Pond 4	Pond 1	Pond 2	Pond 3	Pond 4
Cyanophyta:								
Anabaena sp. Bory								
A. *viguieri* Denis & Fremy								
Anabaenopsis elenkinii Miller								
Chroococcus dispersus (Keissl.) Lemm.								
Dactylococcopsis acicularis Lemm.								
Lyngbya sp. Agardh								
Merismopedia tenuissima Lemm.								
Microcystis aeruginosa Kuetz.	45							
Oscillatoria sp. Vaucher								
O. acutissima Kufferath								
O. hamelii Fremy								
O. *limnetica* Lemmermann								
O. subbrevis Schmidle			225	315			12255	
O. tenuis var. *tergestina* (Kuetz.) Rabenhorst								
Rhabdoderma sigmoidea fa. *minor* Moore & Carter						406	135	
Spirulina nordstedtii Gomont								
S. *princeps* (West & West) G. S. West								
Chlorophyta:								
Acanthosphaera zachariasi Lemm.			90	90	135	45	90	90
Ankistrodesmus falcatus (Corda) Ralfs	811	1757	1307	541	1712	1036	225	541
A. *spiralis* (Turner) Lemm.	90	135	811	90	90	180	45	135
Characium limneticum Lemm.								
Chlamydomonas sp. Ehr.								
Chlorella vulgaris Beyerinck	180	450	180	135		45		
Chodatella chodati (Bernard) Ley.				45				
Cladophora sp. Kuetz.								
Closterium sp. Nitzsch								
Cosmarium sp. Corda								
Crucigenia quadrata Morren		45						
C. *tetrapedia* (Kirch.) West & West	766	1126	135	180	856	541	406	315
Dictyosphaerium pulchellum Wood								
Echinosphaerella limnetica G. M. Smith								
Euastrum Ehr.								
Franceia droescheri (Lemm.) G. M. Smith								
F. ovalis (France) Lemm.								
F. tuberculata G. M. Smith	90							
Golenkinia radiata (Chod.) Wille				45	45			
Green globose colony cf. *Coelastrum* Naegeli *in* Kuetz.								
Kirchneriella obesa (W. West) Schmidle				90				45
Lagerheimia longiseta (Lemm.) Printz			45					
L. *quadriseta* (Lemm.) G. M. Smith								
L. *subsala* Lemm.								
Mougeotia sp. (C. A. Agardh) Wittrock								
Oedogonium sp. Link								
Oocystis eremosphaeria G. M. Smith								
O. *gloeocystiformis* Borge								
Pandorina morum (Muell.) Bory								
Pediastrum duplex Meyen								
P. *tetras* (Ehren.) Ralfs								
Planktosphaeria gelatinosa G. M. Smith								
Pleurotaenium Naeg.								
Scenedesmus abundans (Kirch.) Chodat	1307	1352	856	1307	1487	586	225	586
S. *bijuga* (Turp.) Lagerheim	496	586	180	406	676	541	90	
S. *dimorphus* (Turp.) Kuetz.				45			45	225
S. *quadricauda* (Turp.) de Brebisson in de Brebisson & Godey	90	180		45	135		45	90
Scenedesmus sp. (2 spines)	315	1577		45	766	721		
Schroederia setigera (Schroed.) Lemm.								
Selenastrum minutum (Naeg.) Collins	901	1262	180	135	1216	1171	856	270
Spondylosium sp. de Brebisson								
Sorastrum americanum (Bohlin) Schmidle								
Tetradesmus Wisconsinense G. M. Smith								
Tetraedron duospinum Ackley								
T. minimum (A. Braun) Hansgirg		90		45				
T. regulare Kuetz.	45			45				
T. *trigonum* (Naeg.) Hansgirg				45				45
Tetrastrum staurogeniaeforme (Schroeder) Lemm.								
Treubaria triappendiculata Bernard								45
Ulothrix sp. Kuetz.								

APPENDIX C_{22} (cont.)

PHYTOPLANKTON

(recorded as numbers per ml)

	21 May 73				29 May 73			
	Pond 1	Pond 2	Pond 3	Pond 4	Pond 1	Pond 2	Pond 3	Pond 4
Chrysophyta:								
Chrysamoeba radians Klebs								
Chrysococcus rufescens Klebs								
Derepyxis sp. Stokes								
Diceras phaseolus Fott							45	
Dinobryon bavaricum Imhof							45	
D. divergens Imhof								
D. sertularia Ehrenberg								45
Kephyrion ovum Pascher				496	145	360		135
Mallomonas acaroides var. moskovensis (Wermel) Krieger								
M. caudata Iwanoff	946		405			45	90	
Ochromonas sp. Wystozki								
Ophiocytium bicuspidatum (Borge) Lemm.								
O. capitatum Wolle	45				135			
Euglenophyta:								
Euglena acus Ehrenberg		45						
E. elastica Prescott								
E. oxyuris Schmarda								
E. sp. No. 1 (40 - 90 long)		45			90			45
E. sp. No. 2 (90 - 120 long)								
Lepocinclis fusiformis (Carter) Lemm.								
L. glabra fa. minor Prescott				45				
L. sphagnophila Lemm.								
Phacus sp. Dujardin								
P. acuminatus Stokes								
P. longicauda (Ehr.) Dujardin								
P. nordstedtii Lemm.								
P. orbicularis Huebner								
P. pseudoswirenkoi Prescott								
P. pyrum (Ehr.) Stein								
P. triqueter (Ehr.) Dujardin								
Strombomonas sp. (Skvortzow)								
S. maxima (Skv.)								
Trachelomonas sp. Ehr.								
T. charkowiensis Swirenko ex Deflandre								
T. cylindrica Ehr.								
T. intermedia Dangeard								
T. lacustris Drezepolski								
T. playfairii Deflandre								
T. robusta Swirenko					45			
T. volvocina Ehr.	496	360			991	405		45
Pyrrhophyta:								
Ceratium hirundinella (O. F. Muell.) Dujardin	45					45		
Glenodinium penardiforme (Linde) Schiller								
G. pulvisculus (Ehr.) Stein			45		90			
G. quadridens (Stein) Schiller						45		
Cryptophyta:								
Rhodomonas lacustris Pascher & Ruttner								
Other Flagellates:								
Grey-green; globose to irregular: unequal flagella, often one quite long; similar to small Chlorella; chloroplast not obvious								
Bacillariophyta:								
Achnanthes Bory		45			45			
Amphipleura pellucida Kuetz.								
Amphora Ehr.								
Caloneis Cleve								
Cocconeis Ehr.				45		45	45	
Cyclotella Kuetz.	4415	4911	1307	2613	5677	1757	1126	2613
Cymbella Agardh		45						
Cymbella microcephala Grun.								
Diploneis Ehr.			45					

APPENDIX C_{22} (cont.)

PHYTOPLANKTON
(recorded as numbers per ml)

	21 May 73				29 May 73			
	Pond 1	Pond 2	Pond 3	Pond 4	Pond 1	Pond 2	Pond 3	Pond 4
Bacillariophyta (cont.):								
Epithemia Brebisson								
Eunotia Ehr.								
Fragilaria Lyngbye		696						
Gomphonema Agardh								
Gyrosigma Hassal								
Melosira Agardh								
Navicula Bory	45	90		180	90		180	180
Neidium Pftz.					45			
Nitzschia acicularis W. Smith								
Nitzschia Hassall		90		135	45	135	90	90
Pinnularia Ehr.								
Rhizosolenia Ehr.								
Rhopalodia gibba (Ehr.) O. Muell.								
Stauroneis Ehr.								
Stephanodiscus Ehr.			45					
Synedra Ehr.	145		1191	225	225		180	270
* *Additions*								
Chlorophyta:								
Elakatothrix gelatinosa Wille	45							
Chrysophyta:								
Chrysococcus cyst.							45	
Bacillariphyta:								
Asterionella formosa Hass				225				180

APPENDIX C_{22} (cont.)

PHYTOPLANKTON

(recorded as numbers per ml)

	5 Jun 73				8 Jun 73			
	Pond 1	Pond 2	Pond 3	Pond 4	Pond 1	Pond 2	Pond 3	Pond 4
Cyanophyta:								
Anabaena sp. Bory								67
A. viguieri Denis & Fremy								
Anabaenopsis elenkinii Miller								45
Chroococcus dispersus (Keissl.) Lemm.								
Dactylococcopsis acicularis Lemm.								
Lyngbya sp. Agardh								
Merismopedia tenuissima Lemm.								
Microcystis aeruginosa Kuetz.								
Oscillatoria sp. Vaucher								
O. acutissima Kufferath								
O. hamelii Fremy								
O. limnetica Lemmermann								
O. subbrevis Schmidle			6150	37959		113	22099	22122
O. tenuis var. tergestina (Kuetz.) Rabenhorst								
Rhabdoderma sigmoidea fa. minor Moore & Carter								
Spirulina nordstedtii Gomont								
S. princeps (West & West) G. S. West								
Chlorophyta:								
Acanthosphaera zachariasi Lemm.	360	901	90	135	1712	315	225	541
Ankistrodesmus falcatus (Corda) Ralfs	315	180	180	315	90	586	360	
A. spiralis (Turner) Lemm.	315	586	45	135	1036	1171	225	90
Characium limneticum Lemm.								
Chlamydomonas sp. Ehr.								
Chlorella vulgaris Beyerinck								
Chodatella chodati (Bernard) Ley.								
Cladophora sp. Kuetz.								
Closterium sp. Nitzsch								
Cosmarium sp. Corda								
Crucigenia quadrata Morren								
C. tetrapedia (Kirch.) West & West	856	1757	451	90	2703	3649	405	180
Dictyosphaerium pulchellum Wood								
Echinosphaerella limnetica G. M. Smith								
Euastrum Ehr.								
Franceia droescheri (Lemm.) G. M. Smith								
F. ovalis (France) Lemm.								
F. tuberculata G. M. Smith								
Golenkinia radiata (Chod.) Wille			180	90	45	45	90	360
Green globose colony cf. Coelastrum Naegeli in Kuetz.					45			
Kirchneriella obesa (W. West) Schmidle								90
Lagerheimia longiseta (Lemm.) Printz			45	90				
L. quadriseta (Lemm.) G. M. Smith								
L. subsala Lemm.					45			
Mougeotia sp. (C. A. Agardh) Wittrock								
Oedogonium sp. Link								
Oocystis eremosphaeria G. M. Smith								
O. gloeocystiformis Borge								
Pandorina morum (Muell.) Bory								
Pediastrum duplex Meyen								
P. tetras (Ehren.) Ralfs								
Planktosphaeria gelatinosa G. M. Smith								
Pleurotaenium Naeg.								
Scenedesmus abundans (Kirch.) Chodat	90	135	451	180	1036	450	541	180
S. bijuga (Turp.) Lagerheim	270	360	451	180	1397	946	901	541
S. dimorphus (Turp.) Kuetz.				135	45	45	90	315
S. quadricauda (Turp.) de Brebisson in de Brebisson & Godey						45	45	135
Scenedesmus sp. (2 spines)	45	135			135	90		45
Schroederia setigera (Schroed.) Lemm.								
Selenastrum minutum (Naeg.) Collins	541	496	2748	586	3649	2658	2118	405
Spondylosium sp. de Brebisson								
Sorastrum americanum (Bohlin) Schmidle								
Tetradesmus Wisconsinense G. M. Smith								
Tetraedron duospinum Ackley								
T. minimum (A. Braun) Hansgirg						45		
T. regulare Kuetz.				90	45			45
T. trigonum (Naeg.) Hansgirg					45		45	
Tetrastrum staurogeniaeforme (Schroeder) Lemm.								
Treubaria triappendiculata Bernard			45	45				
Ulothrix sp. Kuetz.								

APPENDIX C_{22} (cont.)

PHYTOPLANKTON
(recorded as numbers per ml)

	5 Jun 73				8 Jun 73			
	Pond 1	Pond 2	Pond 3	Pond 4	Pond 1	Pond 2	Pond 3	Pond 4
Chrysophyta:								
Chrysamoeba radians Klebs								
Chrysococcus rufescens Klebs								
Derepyxis sp. Stokes								
Diceras phaseolus Fott		90			45	45		
Dinobryon bavaricum Imhof								
D. divergens Imhof								
D. sertularia Ehrenberg	45							
Kephyrion ovum Pascher	45	270		45	225	270		45
Mallomonas acaroides var. moskovensis (Wermel) Krieger								
M. caudata Iwanoff								
Ochromonas sp. Wystozki								
Ophiocytium bicuspidatum (Borge) Lemm.								
O. capitatum Wolle					180	45	90	45
Euglenophyta:								
Euglena acus Ehrenberg								
E. elastica Prescott						45		45
E. oxyuris Schmarda								
E. sp. No. 1 (40 - 90 long)		45		45				
E. sp. No. 2 (90 - 120 long)								
Lepocinclis fusiformis (Carter) Lemm.								
L. glabra fa. minor Prescott								
L. sphagnophila Lemm.								
Phacus sp. Dujardin						45		
P. acuminatus Stokes						45		
P. longicauda (Ehr.) Dujardin								
P. nordstedtii Lemm.								
P. orbicularis Huebner								
P. pseudoswirenkoi Prescott								
P. pyrum (Ehr.) Stein								
P. triqueter (Ehr.) Dujardin								
Strombomonas sp. (Skvortzow)								
S. maxima (Skv.)								
Trachelomonas sp. Ehr.						45		
T. charkowiensis Swirenko ex Deflandre								
T. cylindrica Ehr.								
T. intermedia Dangeard								
T. lacustris Drezepolski								
T. playfairii Deflandre								
T. robusta Swirenko	45	45				90		
T. volvocina Ehr.		225	405	45	135	315		
Pyrrhophyta:								
Ceratium hirundinella (O. F. Muell.) Dujardin					45	90		
Glenodinium penardiforme (Linde) Schiller								
G. pulvisculus (Ehr.) Stein			45				45	90
G. quadridens (Stein) Schillar	45	45		135			135	
Cryptophyta:								
Rhodomonas lacustris Pascher & Ruttner								
Other Flagellates:								
Grey-green; globose to irregular; unequal flagella, often one quite long; similar to small Chlorella; chloroplast not obvious								
Bacillariophyta:								
Achnanthes Bory	45							
Amphipleura pellucida Kuetz.								
* Amphora Ehr.					45			45
Caloneis Cleve					45		45	
Cocconeis Ehr.								
Cyclotella Kuetz.	1622	631	2208	2388	3785	2974	4145	1847
Cymbella Agardh								
Cymbella microcephala Grun.								
Diploneis Ehr.								

APPENDIX C_{22} (cont.)

PHYTOPLANKTON
(recorded as numbers per ml)

	5 Jun 73				8 Jun 73			
	Pond 1	Pond 2	Pond 3	Pond 4	Pond 1	Pond 2	Pond 3	Pond 4
Bacillariophyta (cont.):								
Epithemia Brebisson								
Eunotia Ehr.								
Fragilaria Lyngbye								
Gomphonema Agardh							45	
Gyrosigma Hassal								
Melosira Agardh								
Navicula Bory		45		45	45		180	45
Neidium Pftz.								
Nitzschia acicularis W. Smith		45	45				45	
Nitzschia Hassall	45		135	45	180	45	135	90
Pinnularia Ehr.								
Rhizosolenia Ehr.								
Rhopalodia gibba (Ehr.) O. Muell.				45				
Stauroneis Ehr.								
Stephanodiscus Ehr.								
Synedra Ehr.	180	45	135	45	540	180	45	180
* Additions								
Chlorophyta:								
Tetraedron caudatum (Corde) Hans.							45	
Bacillariophyta:								
Asterionella formosa Hass				90				

APPENDIX C_{22} (cont.)

PHYTOPLANKTON

(recorded as numbers per ml)

	14 Jun 73							
	Pond 1	Pond 2	Pond 3	Pond 4	Pond	Pond	Pond	Pond
Cyanophyta:								
* Anabaena sp. Bory				1131				
A. viguieri Denis & Fremy								
Anabaenopsis elenkinii Miller								
Chroococcus dispersus (Keissl.) Lemm.								
Dactylococcopsis acicularis Lemm.								
Lyngbya sp. Agardh								
Merismopedia tenuissima Lemm.								
Microcystis aeruginosa Kuetz.	135	45						
Oscillatoria sp. Vaucher								
O. acutissima Kufferath								
O. hamelii Fremy								
O. limnetica Lemmermann								
O. subbrevis Schmidle			47					
O. tenuis var. tergestina (Kuetz.) Rabenhorst								
Rhabdoderma sigmoidea fa. minor Moore & Carter								
Spirulina nordstedtii Gomont								
S. princeps (West & West) G. S. West								
Chlorophyta:								
Acanthosphaera zachariasi Lemm.	2118	586	4877	2705				
Ankistrodesmus falcatus (Corda) Ralfs	766	135	94	639				
A. spiralis (Turner) Lemm.	45	315	281	49				
Characium limneticum Lemm.								
Chlamydomonas sp. Ehr.								
* Chlorella vulgaris Beyerinck								
Chodatella chodati (Bernard) Ley.	135	45	94					
Cladophora sp. Kuetz.								
Closterium sp. Nitzsch								
Cosmarium sp. Corda		45						
Crucigenia quadrata Morren								
C. tetrapedia (Kirch.) West & West	4460	1982	1313	49				
Dictyosphaerium pulchellum Wood								
* Echinosphaerella limnetica G. M. Smith								
Euastrum Ehr.								
Franceia droescheri (Lemm.) G. M. Smith								
F. ovalis (France) Lemm.								
F. tuberculata G. M. Smith								
Golenkinia radiata (Chod.) Wille	90		469	418				
Green globose colony cf. Coelastrum Naegeli in Kuetz.				25				
Kirchneriella obesa (W. West) Schmidle								
Lagerheimia longiseta (Lemm.) Printz				25				
L. quadriseta (Lemm.) G. M. Smith								
L. subsala Lemm.								
Mougeotia sp. (C. A. Agardh) Wittrock								
Oedogonium sp. Link								
Oocystis eremosphaeria G. M. Smith								
O. gloeocystiformis Borge								
Pandorina morum (Muell.) Bory								
Pediastrum duplex Meyen			94					
P. tetras (Ehren.) Ralfs								
Planktosphaeria gelatinosa G. M. Smith								
Pleurotaenium Naeg.								
Scenedesmus abundans (Kirch.) Chodat	586	270	1594	861				
S. bijuga (Turp.) Lagerheim	2838	991	1313	418				
S. dimorphus (Turp.) Kuetz.			1125	393				
S. quadricauda (Turp.) de Brebisson in de Brebisson & Godey	135	45	375	271				
Scenedesmus sp. (2 spines)	45	45						
Schroederia setigera (Schroed.) Lemm.				148				
Selenastrum minutum (Naeg.) Collins	3109	1622	5627	221				
Spondylosium sp. de Brebisson								
Sorastrum americanum (Bohlin) Schmidle								
Tetradesmus Wisconsinense G. M. Smith								
Tetraedron duospinum Ackley								
T. minimum (A. Braun) Hansgirg			94	49				
T. regulare Kuetz.	45							
T. trigonum (Naeg.) Hansgirg		90	94					
Tetrastrum staurogeniaeforme (Schroeder) Lemm.								
Treubaria triappendiculata Bernard				25				
Ulothrix sp. Kuetz.								

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APPENDIX C_{22} (cont.)

PHYTOPLANKTON
(recorded as numbers per ml)

	14 Jun 73							
	Pond 1	Pond 2	Pond 3	Pond 4	Pond	Pond	Pond	Pond
Chrysophyta:								
Chrysamoeba radians Klebs								
Chrysococcus rufescens Klebs		45						
Derepyxis sp. Stokes								
Diceras phaseolus Fott								
Dinobryon bavaricum Imhof			172					
D. divergens Imhof								
D. sertularia Ehrenberg	1667	1081	188					
Kephyrion ovum Pascher	270	450						
Mallomonas acaroides var. moskovensis (Wermel) Krieger								
M. caudata Iwanoff								
Ochromonas sp. Wystozki	225							
Ophiocytium bicuspidatum (Borge) Lemm.				25				
O. capitatum Wolle	180	45	188					
Euglenophyta:								
Euglena acus Ehrenberg	45	180						
E. elastica Prescott		45						
E. oxyuris Schmarda								
E. sp. No. 1 (40 - 90 long)		45		25				
E. sp. No. 2 (90 - 120 long)				49				
Lepocinclis fusiformis (Carter) Lemm.								
L. glabra fa. minor Prescott								
L. sphagnophila Lemm.								
Phacus sp. Dujardin								
P. acuminatus Stokes	90							
P. longicauda (Ehr.) Dujardin								
P. nordstedtii Lemm.								
P. orbicularis Huebner	45	45		25				
P. pseudoswirenkoi Prescott								
P. pyrum (Ehr.) Stein								
P. triqueter (Ehr.) Dujardin								
Strombomonas sp. (Skvortzow)								
S. maxima (Skv.)		90						
Trachelomonas sp. Ehr.								
T. charkowiensis Swirenko ex Deflandre								
T. cylindrica Ehr.								
T. intermedia Dangeard								
T. lacustris Drezepolski								
T. playfairii Deflandre								
T. robusta Swirenko				25				
T. volvocina Ehr.			188					
Pyrrhophyta:								
Ceratium hirundinella (O. F. Muell.) Dujardin		90						
Glenodinium penardiforme (Linde) Schiller				49				
G. pulvisculus (Ehr.) Stein								
G. quadridens (Stein) Schiller			281	271				
Cryptophyta:								
Rhodomonas lacustris Pascher & Ruttner				344				
Other Flagellates:								
Grey-green; globose to irregular: unequal flagella, often one quite long; similar to small Chlorella; chloroplast not obvious								
Bacillariophyta:								
Achnanthes Bory			94					
Amphipleura pellucida Kuetz.								
Amphora Ehr.	45							
Caloneis Cleve								
Cocconeis Ehr.								
Cyclotella Kuetz.	6082	2613	1876	1500				
Cymbella Agardh	45							
Cymbella microcephala Grun.								
Diploneis Ehr.		45						

PHYTOPLANKTON
(recorded as numbers per ml)

	14 Jun 73							
	Pond 1	Pond 2	Pond 3	Pond 4	Pond	Pond	Pond	Pond
Bacillariophyta (cont.).								
Epithemia Brebisson								
Eunotia Ehr.								
Fragilaria Lyngbye								
Gomphonema Agardh								
Gyrosigma Hassal								
Melosira Agardh								
Navicula Bory	135	90	469	25				
Neidium Pftz.								
Nitzschia acicularis W. Smith	135	180						
Nitzschia Hassall	180	180		98				
Pinnularia Ehr.								
Rhizosolenia Ehr.								
Rhopalodia gibba (Ehr.) O. Muell.								
Stauroneis Ehr.								
Stephanodiscus Ehr.								
Synedra Ehr.	1847	225	469	295				
* Additions								
Cyanophyta:								
Anabaena augustumalis var. marchia Lemm				1131				
Chlorphyta:								
Chlorococcum sp.			13036					

APPENDIX C$_{23}$

TOTAL ZOOPLANKT 'IC ORGANISMS PER HAUL

TAXA	8/2/72 Pond 1	Pond 2	Pond 3	Pond 4	8/11/72 Pond 1	Pond 2	Pond 3	Pond 4
Rotifera								
Brachionidae								
Brachionus calyciflorus	16				496	24	8	8
B. urceolares	8					[illegible]		
B. angularis	4	8				8		
B. quadrindentata			4		4	10		
B. havanaenis								
B. sp.								
Keratella cochlearis	304	560	68	292	212	528	124	12
K. quadrata		8						
K. sp.								
Notholca sp.	16		8	16	44			8
Trichotria tetractis	12			12	4	24		
Brachionus sp.								
B. havanensis								
Lecanidae								
Lecane luna				4	44			
L. sp.				12				
Monostyla sp.		4		4	4	8	4	
Trichocercidae								
Trichocerca sp.	12	8		8		4		
Gastropidae								
Chromogaster ovatis				12				
Asplanchnidae								
Asplanchna priodonta	12	16	12	8	4	4	4	
Synchaetidae								
Ploesoma truncatum			28					
Polyarthra sp.	12	36				60	28	16
Collothecidae								
Cupelopagis vorax								
Copepoda								
Cyclopidae								
Cyclops bicuspidatus thomasi	12	52	8	24	8	8		
C. vernalis		4						
Tropocyclops prasinus				16				
Cladocera								
Daphniidae								
Daphnia sp.		32		16				
Holopidae								
Holopedium gibberus				4				
Bosmina longirostris								
Chydroridae								
Chydorus sphaericus								4
Alona affinis				24				
Nauplii	8	172	60	568	48	40	12	8
Rhizopoda								
Difflugia sp.								
N	416	900	188	1020	870	732	180	56
S	11	11	8	15	10	12	6	6

APPENDIX C_{23} (cont.)

TOTAL ZOOPLANKTONIC ORGANISMS PER HAUL

TAXA	8/18/72 Pond 1	Pond 2	Pond 3	Pond 4	8/28/72 Pond 1	Pond 2	Pond 3	Pond 4
Rotifera								
Brachionidae								
Brachionus calyciflorus	292	52	4		28	68	48	8
B. urceolares								
B. angularis	4	8					16	12
B. quadrindentata	12	4					4	
B. havanaenis							12	
B. sp.	8							
Keratella cochlearis	84	568	28	4	424	48	24	4
K. quadrata								
K. sp.								
Notholca sp.	8							
Trichotria tetractis								
Brachionus sp.								
B. havanensis								
Lecanidae								
Lecane luna								
L. sp.								
Monostyla sp.								
Trichocercidae								
Trichocerca sp.		8						
Gastropidae								
Chromogaster ovatis								
Asplanchnidae								
Asplanchna priodonta		4				16		
Synchaetidae								
Ploesoma truncatum								
Polyarthra sp.	92	144			164	84	44	
Collothecidae								
Cupelopagis vorax		20						4
Copepoda								
Cyclopidae								
Cyclops bicuspidatus thomasi	4	16						
C. vernalis								
Tropocyclops prasinus								
Cladocera								
Daphniidae								
Daphnia sp.								
Holopidae								
Holopedium gibberus								
Bosmina longirostris								
Chydroridae								
Chydorus sphaericus								
Alona affinis								
Nauplii	16	36				4	32	32
Rhizopoda								
Difflugia sp.	12	20	148	124	132	100	72	108
N	532	880	180	128	748	320	252	168
S	10	11	3	2	4	6	8	6

APPENDIX C_{23} (cont.)

TOTAL ZOOPLANKTONIC ORGANISMS PER HAUL

TAXA	9/8/72 Pond 1	Pond 2	Pond 3	Pond 4	9/15/72 Pond 1	Pond 2	Pond 3	Pond 4
Rotifera								
Brachionidae								
Brachionus calyciflorus								
B. urceolares			8	8	28	48		
B. angularis	56	24	8		156	68	56	24
B. quadrindentata								
B. havanaenis			24					
B. sp.						16	8	
Keratella cochlearis	128	32	48	32	60	32	168	16
K. quadrata								
K. sp.						16		
Notholca sp.				8				
Trichotria tetractis								
Brachionus sp.								
B. havanensis								
Lecanidae								
Lecane luna								
L. sp.								
Monostyla sp.					8			
Trichocercidae								
Trichocerca sp.								
Gastropidae								
Chromogaster ovatis								
Asplanchnidae								
Asplanchna priodonta						8		
Synchaetidae								
Ploesoma truncatum								
Polyarthra sp.	256	272		24	120	176	72	8
Collothecidae								
Cupelopagis vorax								
Copepoda								
Cyclopidae								
Cyclops bicuspidatus thomasi								
C. vernalis								
Tropocyclops prasinus								
Cladocera								
Daphniidae								
Daphnia sp.								
Holopidae								
Holopedium gibberus								
Bosmina longirostris	8	8				8		
Chydroridae								
Chydorus sphaericus								
Alona affinis								
Nauplii	32	16	8	8		40	8	8
Rhizopoda								
Difflugia sp.	120	136	32	48	36	56	16	32
N	600	488	128	128	408	468	328	88
S	6	6	6	6	6	10	6	5

APPENDIX C_{23} (cont.)

TOTAL ZOOPLANKTONIC ORGANISMS PER HAUL

TAXA	9/22/72 Pond 1	Pond 2	Pond 3	Pond 4	9/29/72 Pond 1	Pond 2	Pond 3	Pond 4
Rotifera								
Brachionidae								
Brachionus calyciflorus	16	48			88	56	36	
B. urceolares								
B. angularis	1184	3160	216	8	1000	3024	2560	
B. quadrindentata								8
B. havanaensis					24	24		
B. sp.		72	64		96			
Keratella cochlearis	120	520	24	8	2968	1760	1484	472
K. quadrata								
K. sp.	8				152	56	48	48
Notholca sp.								
Trichotria tetractis								
Brachionus sp.								
B. havanensis								
Lecanidae								
Lecane luna								
L. sp.								
Monostyla sp.								
Trichocercidae								
Trichocerca sp.								
Gastropidae								
Chromogaster ovatis								
Asplanchnidae								
Asplanchna priodonta	8	56			16	32	32	
Synchaetidae								
Ploesoma truncatum								
Polyarthra sp.	104	184		8	496	392	408	16
Collothecidae								
Cupelopagis vorax								
Copepoda								
Cyclopidae								
Cyclops bicuspidatus thomasi				8	8	28	8	
C. vernalis								
Tropocyclops prasinus								
Cladocera								
Daphniidae								
Daphnia sp.								
Holopidae								
Holopedium gibberus								
Bosmina longirostris	8	112			40	72	60	
Chydroridae								
Chydorus sphaericus								
Alona affinis								
Nauplii		72	8	8	32	64	160	
Rhizopoda								
Difflugia sp.	48	8	8		96	156	32	24
N	1496	4232	322	40	5034	5664	4828	568
S	8	9	5	5	13	11	10	5

TOTAL ZOOPLANKTONIC ORGANISMS PER HAUL

	10/2/72				10/9/72			
TAXA	Pond 1	Pond 2	Pond 3	Pond 4	Pond 1	Pond 2	Pond 3	Pond 4
Rotifera								
Brachionidae								
Brachionus calyciflorus	16	40	12	36		104		
B. urceolares								
B. angularis	160	488	106	392	16	168		
B. quadrindentata								
B. havanaenis								
B. sp.				4		24		
Keratella cochlearis	896	2460	784	352	5840	6136	592	600
K. quadrata								
K. sp.	64	112	48	48	336	32	24	8
Notholca sp.								
Trichotria tetractis								
Brachionus sp.								
B. havanensis								
Lecanidae								
Lecane luna								
L. sp.								
Monostyla sp.								
Trichocercidae								
Trichocerca sp.								
Gastropidae								
Chromogaster ovatis								
Asplanchnidae								
Asplanchna priodonta	16	64		16	8			
Synchaetidae								
Ploesoma truncatum								
Polyarthra sp.	160	768		36	256	1184	16	8
Collothecidae								
Cupelopagis vorax								
Copepoda								
Cyclopidae								
Cyclops bicuspidatus thomasi		8				8		
C. vernalis								
Tropocyclops prasinus						136		
Cladocera								
Daphniidae								
Daphnia sp.								
Holopidae								
Holopedium gibberus								
Bosmina longirostris	8		32		24	128		
Chydroridae								
Chydorus sphaericus								
Alona affinis								
Nauplii		16	8	8		48		16
Rhizopoda								
Difflugia sp.	144	900			80	3536	40	72
N	1464	4856	986	892	6560	11504	672	704
S	8	9	6	8	7	11	4	5

APPENDIX C_{23} (cont.)

TOTAL ZOOPLANKTONIC ORGANISMS PER HAUL

TAXA	October 16, 1972 Pond 1	Pond 2	Pond 3	Pond 4	October 24, 1972 Pond 1	Pond 2	Pond 3	Pond 4
Rotifera								
Brachionidae								
Brachionus calyciflorus				8				
B. urceolares								
B. angularis		8						
B. quadrindentata								
B. havanaenis								
B. sp.								
Keratella cochlearis	4392	4912	248	840				
K. quadrata								
K. sp.	56	8		8				
Notholca sp.								
Trichotria tetractis								
Brachionus sp.	8							
B. havanensis								
Lecanidae								
Lecane luna								
L. sp.								
Monostyla sp.								
Trichocercidae								
Trichocerca sp.		16						
Gastropidae								
Chromogaster ovatis								
Asplanchnidae								
Asplanchna priodonta								
Synchaetidae								
Ploesoma truncatum								
Polyarthra sp.	24	378	24	36				
Collothecidae								
Cupelopagis vorax								
Copepoda								
Cyclopidae								
Cyclops bicuspidatus thomasi		24						
C. vernalis								
Tropocyclops prasinus		16						
Cladocera								
Daphniidae								
Daphnia sp.								
Holopidae								
Holopedium gibberus								
Bosmina longirostris	8	40						
Chydroridae								
Chydorus sphaericus								
Alona affinis								
Nauplii		8						
Rhizopoda								
Difflugia sp.	32	360	32	32				
N	4520	5770	304	924				
S	6	10	3	5				

APPENDIX C_{24}

1972 ZOOPLANKTON RICHNESS AND SIMILARITY COEFFICIENT CALCULATIONS

Date	Pond	S-1/lnN	S/ N	C/(a+b-c)	2 c/a+b
2 Aug 72	1	1.6581	0.5393	0.47	0.64
	2	1.4700	0.3666		
	3	1.3367	0.5834	0.28	0.43
	4	2.0209	0.4696		
11 Aug 72	1	1.3296	0.3390	0.57	0.73
	2	1.6677	0.4435		
	3	0.9628	0.4472	0.50	0.67
	4	1.2421	0.8017		
18 Aug 72	1	1.4338	0.4335	0.62	0.76
	2	1.4749	0.3708		
	3	0.3851	0.2236	0.67	0.80
	4	0.2061	0.1767		
28 Aug 72	1	0.4533	0.462	0.67	0.80
	2	0.8668	0.3354		
	3	1.2659	0.5939	0.56	0.71
	4	0.9758	0.4629		

APPENDIX C_{24} (cont.)

1972 ZOOPLANKTON RICHNESS AND SIMILARITY COEFFICIENT CALCULATIONS

Date	Pond	S-1/lnN	S/ N	C/(a+b-c)	2 c/a+b
8 Sep 72	1	0.7816	0.2034	1.0	1.0
	2	0.8077	0.2716		
	3	1.0305	0.5303	0.50	0.67
	4	1.0305	0.5303		
15 Sep 72	1	0.9977	0.2970	0.45	0.63
	2	1.4638	0.4623		
	3	0.8631	0.3313	0.83	0.91
	4	0.8934	0.5330		
22 Sep 72	1	0.9575	0.0270	0.70	0.82
	2	0.9580	0.1384		
	3	0.6926	0.2786	0.43	0.60
	4	1.0843	0.7905		
29 Sep 72	1	1.4078	0.1832	0.85	0.92
	2	1.1572	0.1462		
	3	1.0610	0.1439	0.36	0.53
	4	0.6307	0.1796		

APPENDIX C_{24} (cont.)

1972 ZOOPLANKTON RICHNESS AND SIMILARITY COEFFICIENT CALCULATIONS

Date	Pond	S-1/1n.N	S/ N	C/(a+b-c)	2 c/a+b
2 Oct 72	1	0.9604	0.2091	0.54	0.71
	2	0.9515	0.1292		
	3	0.7253	0.1911	0.56	0.72
	4	1.0304	0.2679		
9 Oct 72	1	0.6826	0.0864	0.50	0.67
	2	1.0695	0.1026		
	3	0.4608	0.1543	0.80	0.89
	4	0.6100	0.1884		
16 Oct 72	1	0.5941	0.0892	0.45	0.63
	2	1.0392	0.1316		
	3	0.3498	0.1721	0.60	0.75
	4	0.5858	0.1645		

APPENDIX C_{25}

TOTAL ZOOPLANKTONIC ORGANISMS PER HAUL

	April 25, 1973				May 14, 1973			
TAXA	Pond 1	Pond 2	Pond 3	Pond 4	Pond 1	Pond 2	Pond 3	Pond 4
Rotifera								
Brachionidae								
Brachionus calyciflorus								
Brachionus urceolaris								
Brachionus angularis	30							20
Brachionus quadrindentata								
Brachionus havanaenis								
Brachionus sp.								
Keratella cochlearis	4600	3700	3600	2000	8800	6700	120	60
Keratella quadrata								
Notholca sp.								
Trichotria tetractis								
Testudinellidae								
Filinia longiseta								
Lecanidae								
Lecane luna								
Lecane sp.								
Monostyla sp.								
Trichocercidae								
Trichocerca capucina					80	140		
Gastropidae								
Chromogaster ovatis								
Asplanchnidae								
Asplanchna priodonta								
Synchaetidae								
Ploesoma truncatum								
Polyarthra sp.		20	100	60				
Collothecidae								
Cupelopagis vorax								
Copepoda								
Cyclopidae								
Cyclops bicuspidatus thomasi								
Cyclops vernalis								
Tropocyclops prasinus								
Calanoidae								
Senecella calanoides								
Nauplii			10					
Cladocera								
Daphniidae								
Daphnia magna								
Bosminidae								
Bosmina longirostris								
Holopedidae								
Holopedium gibberum								
Chydoridae								
Chydorus sphaericus								
Rhizopoda								
Difflugia sp.					80			

APPENDIX C_{25} (cont.)

TOTAL ZOOPLANKTONIC ORGANISMS PER HAUL

	May 21, 1973				May 29, 1973			
TAXA	Pond 1	Pond 2	Pond 3	Pond 4	Pond 1	Pond 2	Pond 3	Pond 4
Rotifera								
Brachionidae								
Brachionus calyciflorus			50		10		20	
Brachionus urceolaris								
Brachionus angularis	40				170	180	30	10
Brachionus quadrindentata								
Brachionus havanaensis								
Brachionus sp.								
Keratella cochlearis	1600	2600	3600	120	450	430	2800	840
Keratella quadrata								
Notholca sp.								10
Trichotria tetractis								
Testudinellidae								
Filinia longiseta					10	10		
Lecanidae								
Lecane luna								
Lecane sp.								
Monostyla sp.				10				
Trichocercidae								
Trichocerca capucina		60			10			
Gastropidae								
Chromogaster ovatis								
Asplanchnidae								
Asplanchna priodonta			20					
Synchaetidae								
Ploesoma truncatum								
Polyarthra sp.	200	120	20		170	380	50	10
Collothecidae								
Cupelopagis vorax								
Copepoda								
Cyclopidae								
Cyclops bicuspidatus thomasi						10		
Cyclops vernalis								
Tropocyclops prasinus								
Calanoidae								
Senecella calanoides								
Nauplii					10		10	
Cladocera								
Daphniidae								
Daphnia magna								
Bosminidae								
Bosmina longirostris		50				10		
Holopedidae								
Holopedium gibberum								
Chydoridae								
Chydorus sphaericus								
Rhizopoda								
Difflugia sp.	100				40	40		

APPENDIX C_{25} (cont.)

TOTAL ZOOPLANKTONIC ORGANISMS PER HAUL

	5 Jun 73				14 Jun 73			
	Pond 1	Pond 2	Pond 3	Pond 4	Pond 1	Pond 2	Pond 3	Pond 4
TAXA								
Rotifera								
Brachionidae								
Brachionus calyciflorus					1900	1400	300	20
Brachionus urceolaris								
Brachionus angularis	250	160			230	700	30	30
Brachionus quadridentata						20	10	
Brachionus havanaensis							60	
Brachionus sp.								
Keratella cochlearis	1500	540	240	50	1000	120	120	60
Keratella quadrata								
Notholca sp.								
Trichotria tetractis								
Testudinellidae								
Filinia longiseta	250	80					30	20
Lecanidae								
Lecane luna	10							
Lecane sp.								
Monostyla sp.								
Trichocercidae								
Trichocerca capucina	280	320						
Gastropidae								
Chromogaster ovalis								
Asplanchnidae								
Asplanchna priodonta					30	30		
Synchaetidae								
Ploesoma truncatum								
Polyarthra sp.	1500	1400	80	10	270	160	100	20
Collothecidae								
Cupelopagis vorax								
Copepoda								
Cyclopidae								
Cyclops bicuspidatus thomasi								
Cyclops vernalis								
Tropocyclops prasinus								
Calanoidae								
Senecella calanoides								
Nauplii					100	640	10	
Cladocera								
Daphniidae								
Daphnia magna								
Bosminidae								
Bosmina longirostris	10	10			50	50		
Holopedidae								
Holopedium gibberum								
Chydoridae								
Chydorus sphaericus								
Rhizopoda								
Difflugia sp.	360	1200			5700	6000	340	10
Number of individuals	4160	3710	320	60	9280	9120	1000	160
Number of taxa	8	7	2	2	8	9	9	6

APPENDIX C_{25} (cont.)

TOTAL ZOOPLANKTONIC ORGANISMS PER HAUL

TAXA	25 Jun 73 Pond 1	Pond 2	Pond 3	Pond 4	10 Jul 73 Pond 1	Pond 2	Pond 3	Pond 4
Rotifera								
Brachionidae								
Brachionus calyciflorus	1600	360	20	20				40
Brachionus urceolaris								
Brachionus angularis	5700	2400	230	100	120	70	40	40
Brachionus quadrindentata								
Brachionus havanaenis								
Brachionus sp.								
Keratella cochlearis	8500	3300	30	140	280	630	320	120
Keratella quadrata								
Notholca sp.								
Trichotria tetractis	360	150	700	50				
Testudinellidae								
Filinia longiseta	320							
Lecanidae								
Lecane luna								
Lecane sp.								
Monostyla sp.								
Trichocercidae								
Trichocerca capucina					40			
Gastropidae								
Chromogaster ovalis								
Asplanchnidae								
Asplanchna priodonta	480	140						
Synchaetidae								
Ploesoma truncatum								
Polyarthra sp.	410	240	30	10				
Collothecidae								
Cupelopagis vorax								
Copepoda								
Cyclopidae								
Cyclops bicuspidatus thomasi				10				
Cyclops vernalis								
Tropocyclops prasinus								
Calanoidae								
Senecella calanoides								
Nauplii	160	80	10	10	160	10	80	120
Cladocera								
Daphniidae								
Daphnia magna								
Bosminidae								
Bosmina longirostris	160	80	20		40	40	40	
Holopedidae								
Holopedium gibberum								
Chydoridae								
Chydorus sphaericus								
Rhizopoda								
Difflugia sp.	3300	3500	290	30	280	200	560	40
Number of Individuals	20990	10300	1330	370	920	950	1040	360
Number of Taxa	10	9	8	8	6	5	5	5

APPENDIX C_{25} (cont.)

TOTAL ZOOPLANKTONIC ORGANISMS PER HAUL

	7 Aug 73				20 Aug 73			
TAXA	Pond 1	Pond 2	Pond 3	Pond 4	Pond 1	Pond 2	Pond 3	Pond 4
Rotifera								
Brachionidae								
Brachionus calyciflorus			40		80	80		
Brachionus urceolaris								
Brachionus angularis	720	40			1080	280	480	160
Brachionus quadridentata								
Brachionus havanaensis							40	
Brachionus sp.								
Keratella cochlearis	240	80	160	40	640	280	160	40
Keratella quadrata								
Nothoica sp.								
Trichotria tetractis								
Testudinellidae								
Filinia longiseta	120	40			160	80	40	
Lecanidae								
Lecane luna								
Lecane sp.								
Monostyla sp.						40		
Trichocercidae								
Trichocerca capucina								
Gastropidae								
Chromogaster ovatis								
Asplanchnidae								
Asplanchna priodonta					40	40		
Synchaetidae								
Ploesoma truncatum								
Polyarthra sp.	160	80			400	640	120	
Collothecidae								
Cupelopagis vorax								
Copepoda								
Cyclopidae								
Cyclops bicuspidatus thomasi								
Cyclops vernalis								
Tropocyclops prasinus						40		
Calanoidae								
Senecella calanoides	80							
Diaptomus sp.	40							
Nauplii	120	40	40	40	120	160		
Cladocera								
Daphniidae								
Daphnia magna								
Bosminidae								
Bosmina longirostris	120			40	160			
Holopedidae								
Holopedium gibberum								
Chydoridae								
Chydorus sphaericus								
Rhizopoda								
Difflugia sp.	240	40	80		760	1360	280	40
Number of Individuals	1840	320	320	120	3440	3000	1120	240
Number of Taxa	9	6	4	3	9	10	6	3

APPENDIX C_{26}

1973 ZOOPLANKTON RICHNESS AND SIMILARITY COEFFICIENT CALCULATIONS

DATE	POND	$S-1/\ln N$	$S/\sqrt{N}$	$C/(a+b-c)$	$2\ c/a+b$
25 Apr 73	1	0.12	0.03		
	2	0.12	0.03	0.33	0.50
	3	0.24	0.05		
	4	0.13	0.04	0.67	0.80
14 May 73	1	0.22	0.03		
	2	0.11	0.02	0.67	0.80
	3	0.00	0.09		
	4	0.22	0.22	0.50	0.67
21 May 73	1	0.26	0.07		
	2	0.50	0.09	0.33	0.50
	3	0.37	0.07		
	4	0.21	0.18	0.20	0.33
29 May 73	1	0.73	0.12		
	2	0.72	0.11	0.56	0.71
	3	0.50	0.09		
	4	0.44	0.14	0.50	0.67
5 Jun 73	1	0.84	0.12		
	2	0.73	0.11	0.88	0.93
	3	0.17	0.11		
	4	0.24	0.26	1.00	1.00

APPENDIX C_{26} (cont.)

1973 ZOOPLANKTON RICHNESS AND SIMILARITY COEFFICIENT CALCULATIONS

continued -

DATE	POND	$S-1/\ln N$	$S/\sqrt{N}$	$C/(a+b-c)$	$2\ c/a+b$
14 Jun 73	1	0.77	0.08	0.89	0.94
	2	0.88	0.09		
	3	1.16	0.29	0.67	0.80
	4	0.99	0.48		
10 Jul 73	1	0.73	0.20	0.83	0.91
	2	0.58	0.16		
	3	0.58	0.16	0.67	0.80
	4	0.68	0.27		
7 Aug 73	1	1.06	0.21	0.67	0.80
	2	0.87	0.34		
	3	0.52	0.22	0.40	0.57
	4	0.42	0.27		
20 Aug 73	1	0.98	0.15	0.73	0.84
	2	1.12	0.18		
	3	0.71	0.18	0.50	0.67
	4	0.36	0.19		

Pond 1 - non-leaded
Pond 2 - control
Pond 3 - leaded
Pond 4 - control

APPENDIX C_{27}

1971 Species Composition
Quantitative Benthos Results of Ponar Dredge Hauls

	POND 1															POND 2														
	8/27			9/19			10/15			11/13			12/13			8/27			9/19			10/15			11/13			12/13		
	A_1	B_2	C_3	A_3	B_3	C_2	A_2	B_1	C_1	A_1	B_2	C_3	A_2	B_3	C_1	A_1	B_2	C_3	A_3	B_3	C_2	A_1	B_3	C_2	A_3	B_3	C_3	A_2	B_1	C_1
Ephemeroptera																														
Caenidae																														
Caenis sp.	3		1	2	1	1	2	1		9	3	2	5	6	8		1		2			2	4	1				5	1	4
Siphlonuridae																														
Siphlonurus sp.	1			1			2			1	6	8	1				2			3			3					7	8	1
Hemiptera																														
Belostomatidae																				1										
Belostoma sp.																														
Corixidae																														
Odonata																														
Coenagrionidae																														
Ischnura sp.			4		2						1	1		1	7					2	1	1	4			3	1	1	7	5
Aeschnidae																														
Anax junius			1			1															1							1	2	
Libellulidae																											1			
Leucorrhinia intacta											3							1												
Pantala flavescens																					1									
Plathemis sp.																														
Trichoptera																														
Hydroptilidae																														
Agraylea sp.																														
Phryganeidae																														
Agrypnia sp.											1																			
Leptoceridae																						4							1	
Leptocella sp.																														
Coleoptera																														
Hydrophilidae																														
Berosus sp.											1																			
Dytiscidae																														
Bidessus sp.						1	1						1																	
Haliplidae																								1						
Haliplus sp.		1						1																						
Diptera																														
Chironomidae	33	5	50	31	8	5		4		8	1	31	11	2	10		58	23	1	12	1	2	1		7	3	20	10	8	107
Dolichopodidae																														
Aphrosylus sp.																														
Ephydridae																														
Ephydra riparia									1																					
Ceratopogonidae																														
Palpomyia sp.		1	4	1		1											1				1			1					1	7
Tabanidae																														
Tabanus sp.			1		1							1																		
Tipulidae																														
Tipula sp.												1																		
Chaoboridae																														
Chaoborus punctipennis			1			2				1		1					2											1		
Chaoborus hydrasennis	1										1																			
Oligochaeta																														
Tubificidae		14	10	1		5	1	2			2	8								3	3		1	2					22	4
Hirudinea																														
Glossiphoniidae																														
Helobdella stagnalis																														
Gastropoda																														
Physidae																														
Physa sp.	3		11	3	8		2	2	7	4	63	6	3	13	2			2	5	15	2	5	5			6			22	
Lymnaeidae																														
Lymnaea sp.																													8	
Planorbidae																														
Menetus sp.																														
Ferrissia sp.																														
Amphipoda																														
Talitridae																														
Hyalella azteca				1	1			1		1	4	3										4	1				1		1	10

APPENDIX C_{27} (continued)

1971 Species Composition
Quantitative Benthos Results of Ponar Dredge Hauls

	POND 3															POND 4														
	8/27			9/10			10/10			11/13			12/13			8/27			9/10			10/10			11/13			12/13		
	A_1	B_2	C_3	A_3	B_3	C_1	A_3	B_3	C_1	A_2	B_2	C_2	A_1	B_1	C_1	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Insecta																														
Ephemeroptera																														
Caenidae																														
Caenis sp.	2	1	1							8			2			1		2				6		1		1			7	1
Siphlonuridae																														
Siphlonurus sp.	1		2		1	3		1		2		1				1	3			3		2		1		4		8	5	3
Hemiptera																														
Belostomatidae																														
Belostoma sp.																														
Corixidae																													1	
Odonata						1																								
Coenagrionidae																														
Ischnura sp.		3	2		1		1	2	1				2	2		1		2		5	3	10	3	1	1		2	8	4	3
Aeschnidae																														
Anax junius														1			2			1										
Libellulidae																														
Leucorrhinia intacta										1																1				
Pantala flavescens	1		1															1											1	
Plathemis sp.																				1									1	
Trichoptera																														
Hydroptilidae																														
Agraylea sp.																							1	1						
Phryganeidae																														
Agrypnia sp.																												1		
Leptoceridae																														
Leptocella sp.														1																
Coleoptera																														
Hydrophilidae																														
Berosus sp.																									1					
Dytiscidae																														
Bidessus sp.				1		1																1								
Haliplidae																														
Haliplus sp.	1	1														1		1												
Diptera																														
Chironomidae	3		43		4	8	1	1	3	11	3	50	4	6	54	29	52	41	1	1	1	18		20	5	11		8	18	20
Dolichopodidae																														
Aphrosylus sp.				1																										
Ephydridae																														
Ephydra riparia																														
Ceratopogonidae																														
Palpomyia sp.	1	1	2			1						1									1			4						
Tabanidae																														
Tabanus sp.																		1		1	1									
Tipulidae																														
Tipula sp.																														
Chaoboridae																														
Chaoborus punctipennis											2				2		2		3					1						
Chaoborus hydrocarnia				1																										
Oligochaeta																														
Tubificidae			2										1					4								4			1	
Hirudinea																														
Glossiphoniidae																														
Helobdella stagnalis															2														1	
Gastropoda																														
Physidae																														
Physa sp.	6	6	2	8	1	11			4	9	1	1	4	22		7	12	8	1	11	54	1	1	1	1	8	33	8	30	1
Lymnaeidae																														
Lymnaea sp.																														
Planorbidae																														
Menetus sp.																				1										
Ferrissia sp.																														
Amphipoda																														
Talitridae																														
Hyalella azteca				1	5	2	24	1	1	19	6	6	4	6	27				6	6	6	13	1	11		9	3	9	14	43

APPENDIX C$_{28}$

1971 DIVERSITY CALCULATIONS

Month	Pond	Station*	Number of Individuals	Number of Species	Shannon Formula		Brillouin Formula			Richness
					H'Prime	Evenness JPR	H	Evenness J	Redundancy	S-1/lnN
8	1	A1	41	5	1.07	0.46	0.89	0.43	0.76	1.08
8	1	B2	21	4	1.30	0.65	1.06	0.63	0.58	0.99
8	1	C3	84	9	1.97	0.62	1.77	0.61	0.49	1.81
9	1	A3	40	7	1.31	0.47	1.07	0.44	0.83	1.63
9	1	B3	17	6	2.15	0.83	1.67	0.82	0.41	1.76
9	1	C2	10	5	1.96	0.84	1.39	0.83	0.65	1.74
10	1	A2	8	5	2.25	0.97	1.54	1.00	0.00	1.92
10	1	B1	12	7	2.58	0.92	1.85	0.93	0.35	2.41
10	1	C1	8	2	0.54	0.54	0.38	0.49	1.00	0.48
11	1	A1	22	6	2.09	0.81	1.70	0.81	0.36	1.62
11	1	B2	85	11	1.61	0.47	1.40	0.45	0.73	2.25
11	1	C3	59	10	2.30	0.69	2.00	0.68	0.46	2.21
12	1	A2	21	5	1.80	0.78	1.46	0.76	0.41	1.31
12	1	B3	22	4	1.48	0.74	1.22	0.72	0.43	0.97
12	1	C1	27	4	1.83	0.92	1.58	0.91	0.12	0.91
8	2	B2	63	4	0.44	0.22	0.36	0.19	0.95	0.72
8	2	C3	26	3	0.62	0.39	0.50	0.36	0.87	0.61
9	2	A3	8	3	1.30	0.82	0.92	0.81	0.52	0.96
9	2	B3	38	7	2.22	0.79	1.90	0.78	0.33	1.65
9	2	C2	10	7	2.65	0.94	1.82	0.97	0.37	2.61
10	2	A1	18	6	2.41	0.93	1.91	0.93	0.15	1.73
10	2	B3	19	7	2.54	0.91	2.00	0.91	0.21	2.04
10	2	C2	5	4	1.92	0.96	1.18	1.00	0.00	1.86
11	2	A3	7	1	0.00	0.00	0.00	0.00	1.00	0.00
11	2	B3	12	3	1.50	0.95	1.18	0.94	0.11	0.80
11	2	C3	23	4	0.77	0.38	0.58	0.34	1.00	0.96
12	2	A2	28	7	2.33	0.83	1.94	0.83	0.30	1.80
12	2	B1	77	11	2.72	0.79	2.45	0.78	0.29	2.30
12	2	C1	144	8	1.49	0.50	1.38	0.48	0.59	1.41
8	3	A1	15	7	2.42	0.86	1.81	0.86	0.45	2.22
8	3	B2	15	5	1.69	0.73	1.28	0.70	0.66	1.48
8	3	C3	54	8	1.38	0.46	1.15	0.43	0.79	1.75

APPENDIX C_{28} (cont.)

1971 DIVERSITY CALCULATIONS

					Shannon Formula			Brillouin Formula		
Month	Pond	Station*	Number of Individuals	Number of Species	H'Prime	Evenness JPR	H	Evenness J	Redundancy	Richness S-1/lnN
9	3	A3	12	5	1.58	0.68	1.13	0.66	1.00	1.61
9	3	B3	12	5	1.95	0.84	1.45	0.84	0.47	1.61
9	3	C1	23	6	2.02	0.78	1.64	0.77	0.42	1.59
10	3	A3	26	3	0.47	0.30	0.36	0.26	1.00	0.61
10	3	B3	5	4	1.92	0.96	1.18	1.00	0.00	1.86
10	3	C1	9	4	1.75	9.88	1.26	0.83	0.41	1.37
11	3	A2	48	6	2.23	0.86	1.99	0.86	0.19	1.29
11	3	B2	11	4	1.79	0.89	1.34	0.89	0.27	1.25
11	3	C2	59	5	0.85	0.40	0.74	0.39	0.76	0.98
12	3	A1	16	6	2.38	0.92	1.84	0.92	1.89	1.80
12	3	B1	37	6	1.77	0.68	1.51	0.67	0.48	1.38
12	3	C1	125	4	0.98	0.49	0.92	0.48	0.57	0.62
8	4	A	40	6	1.31	0.51	1.10	0.48	0.72	1.36
8	4	B	71	5	1.25	0.54	1.12	0.52	0.57	0.94
8	4	C	61	8	1.67	0.56	1.45	0.54	0.62	1.70
9	4	A	10	4	1.69	0.84	1.23	0.84	0.45	1.30
9	4	B	30	9	2.54	0.80	2.08	0.80	0.39	2.35
9	4	C	96	6	0.78	0.30	0.69	0.28	0.83	1.10
10	4	A	63	7	2.00	0.71	1.80	0.70	0.38	1.45
10	4	B	5	4	1.92	0.96	1.18	1.00	0.00	1.86
10	4	C	41	9	2.13	0.67	1.80	0.66	0.54	2.15
11	4	A	8	4	1.55	0.77	1.05	0.74	1.00	1.44
11	4	B	38	7	2.44	0.87	2.11	0.87	0.20	1.65
11	4	C	38	3	0.69	0.44	0.59	0.41	0.73	0.55
12	4	A	37	6	2.39	0.92	2.09	0.92	0.11	1.38
12	4	B	78	11	2.54	0.73	2.28	0.73	0.36	2.30
12	4	C	71	6	1.51	0.58	1.37	0.57	0.52	1.17

*refer to Figure 7 this report

APPENDIX C_{29}

1971 SPECIES DIVERSITY INDICES - Pooled Data

				Shannon Formula		Brillouin Formula			
Month	Pond	Number of Individuals	Number of Species	H'Prime	Evenness JPR	H	Evenness J	Redundancy	Richness S-1/lnN
8	1	146	12	1.96	0.55	1.81	0.54	0.55	2.21
9	1	72	11	2.19	0.63	1.92	0.62	0.52	2.34
10	1	28	10	2.75	0.83	2.21	0.82	0.39	2.70
11	1	166	14	2.50	0.66	2.33	0.65	0.41	2.54
12	1	69	6	2.08	0.81	1.91	0.80	0.24	1.18
8	2	89	6	0.57	0.22	0.48	0.20	0.94	1.11
9	2	56	11	2.59	0.75	2.24	0.74	0.39	2.48
10	2	42	10	3.05	0.92	2.61	0.92	0.14	2.41
11	2	42	5	1.33	0.57	1.15	0.55	0.59	1.07
12	2	249	14	2.66	0.70	2.52	0.69	0.35	2.36
8	3	84	9	2.17	0.68	1.95	0.67	0.41	1.81
9	3	47	9	2.35	0.74	2.03	0.74	0.40	2.08
10	3	39	5	1.54	0.66	1.33	0.64	0.48	1.09
11	3	118	8	1.92	0.64	1.78	0.63	0.43	1.47
12	3	179	10	1.79	0.54	1.68	0.53	0.53	1.73
8	4	172	11	1.54	0.45	1.42	0.43	0.65	1.94
9	4	136	11	1.62	0.47	1.47	0.45	0.65	2.04
10	4	108	9	2.30	0.72	2.12	0.72	0.34	1.71
11	4	84	9	2.18	0.69	1.97	0.68	0.41	1.81
12	4	186	12	2.45	0.68	2.31	0.68	0.37	2.10

APPENDIX C_{30}

1971 BIOMASS
SUMMARY OF QUANTITATIVE BENTHOS RESULTS

	Non-leaded gas			Control			Leaded gas			Control		
	Pond 1			Pond 2			Pond 3			Pond 4		
	A1	B2	C3	A1	B2	C3	A1	B2	C3	A3	B3	C3
8/27/71												
Total Number	40	7	84	--	65	24	15	15	54	40	71	61
No. of Species	4	3	9	--	5	2	7	5	8	6	5	7
Biomass g/ft^2	.05ml	negl.	1.4	--	.70	.10	negl.	.25	.25	.20	.80	.20
9/19/71	A3	B3	C2	A3	B3	C2	A3	B3	C1	A1	B2	C1
Total Number	41	17	15	19	27	9	12	12	29	20	30	97
No. of Species	8	6	6	3	7	6	5	5	8	4	9	7
Biomass g/ft^2	.10	.15	.05	.05	.20	.60	.05	.05	.10	.15	.55	.40
10/15/71	A2	B1	C1	A1	B3	C2	A3	B3	C1	A2	B2	C2
Total Number	11	13	10	18	19	5	26	5	9	64	4	42
No. of Species	6	7	4	6	7	4	3	4	4	8	3	10
Biomass g/ft2	.05	.40	.05	.05	.15	negl.	.10	.05	.05	.30	.05	.10
11/13/71	A1	B2	C3	A3	B3	C3	A2	B2	C2	A3	B3	C2
Total Number	21	85	58	8	12	24	48	11	59	8	37	38
No. of Species	5	12	9	2	3	5	6	3	5	4	6	3
Biomass g/ft^2	.20	.70	.20	negl.	.20	.40	.25	.10	.20	.05	.10	.20
12/31/71	A2	B3	C1	A2	B1	C1	A1	B1	C1	A2	B1	C1
Total Number	21	23	27	30	77	146	17	37	125	37	76	71
No. of Species	5	5	4	7	11	9	6	6	4	6	9	6
Biomass	.05	.05	.20	.50	.70	.20	.10	.80	.40	.15	.20	.35

APPENDIX C_{31}

QUANTITATIVE BENTHOS RESULTS

(Organisms /m ^{2})

Pond 1

	5/25			7/27			8/8		
	A	B	C	A	B	C	A	B	C
Ephemeroptera									
Caenis sp.	208	95	76	76	-	-	-	-	-
Siphlonurus sp.	-	-	-	-	-	-	-	-	-
Odonata									
Anax junius sp.	-	-	-	-	-	-	-	-	-
Enallagma sp.	-	19	19	-	-	-	-	-	-
Trichoptera									
Leptocella sp.	19	170	-	-	-	-	-	-	-
Coleoptera									
Berosus sp.	-	-	-	-	-	-	-	-	-
Dubiraphia sp.	-	-	-	-	-	-	-	-	-
Onychylis sp.	-	-	-	-	-	-	-	-	-
Peltodytes sp.	-	-	-	-	-	-	-	-	-
Diptera									
Chaoborus punctipennis	-	-	-	-	57	114	76	284	567
Culex sp.	-	-	-	-	-	-	-	-	-
Palpomiya tibialis	-	-	19	-	-	-	-	-	-
Tabanus sp.	-	-	-	-	-	-	-	-	-
Chironomidae									
Chironomus sp. No. 1	-	-	-	-	-	-	-	-	-
Chironomus sp. No. 2	-	-	-	-	-	-	-	-	-
Chironomus (Cryptochironomus)	-	-	-	-	-	-	-	-	-
Chironomus (Dicrotendipes)	-	-	-	-	-	-	-	-	-
Chironomus (Harnischia)	-	-	-	-	-	-	-	38	-
Chironomus (Kiefferulus)	-	-	-	-	-	-	-	-	-
Chironomus tentans	-	-	-	57	-	-	170	57	95
Clinotanypus sp.	-	-	-	-	-	-	-	-	-
Glyptotendipes sp.	-	-	-	-	-	-	-	-	-
Goeldichironomus sp.	-	-	-	-	-	-	-	-	-
Nannocladius sp.	-	-	-	-	-	-	-	-	-
Orthocladius sp.	-	-	-	-	-	-	-	-	-
Paralauterborniella sp.	-	-	-	-	-	-	38	-	-
Pentaneura flavifrons	-	-	57	-	-	-	-	-	-
Polypedilum sp.	-	-	-	-	19	-	-	-	-
Procladius sp.	19	-	-	-	-	-	-	-	-
Pseudochironomus sp.	-	-	-	-	-	-	-	-	-
Stenochironomus sp.	-	-	-	-	-	-	-	-	-
Tanytarsus sp.	-	19	-	-	-	-	19	-	19
Tanypus sp.	-	-	-	-	-	-	-	-	-
Oligochaeta									
Tubificidae	76	76	113	-	-	19	-	-	-
Basommatophora									
Physa sp.	-	170	19	57	-	-	-	-	-
Sphaerium sp.	-	-	-	-	-	-	-	-	-
Amphipoda									
Hyallela azteca	-	-	-	-	-	19	-	-	-
Hydracarina	-	-	-	-	-	-	-	-	-
Total number of species	4	6	6	3	2	3	4	2	4
Total number of organisms per square meter	322	549	303	190	76	152	303	341	719
Biomass (vol. displacement in ml.)	0.1	0.2	0.1	0.05	-	.03	.1	.75	.15
$\bar{x}$ Biomass		0.13			.03			0.33	
– = negligible biomass									
0 = no biomass									
S		9			7			5	
N		1174			418			1363	

APPENDIX C_{31} (cont.)

QUANTITATIVE BENTHOS RESULTS
(Organisms /m ^{2})

Pond 1

	9/6			10/12			11/10			12/29		
	A	B	C	A	B	C	A	B	C	A	B	C
Ephemeroptera												
Caenis sp.	-	-	-	-	-	-	-	-	-	-	-	-
Siphlonurus sp.	-	-	-	-	-	-	-	-	-	-	-	-
Odonata												
Anax junius sp.	-	-	-	-	-	-	-	-	-	-	-	-
Enallagma sp.	-	-	-	-	-	-	-	-	-	-	-	-
Trichoptera												
Leptocella sp.	-	-	-	-	-	-	-	-	-	-	-	-
Coleoptera												
Berosus sp.	-	-	-	-	-	-	-	-	-	-	-	-
Dubiraphia sp.	-	-	-	-	-	-	-	-	-	-	-	-
Onychylis sp.	-	-	-	-	-	-	-	-	-	-	-	-
Peltodytes sp.	-	-	-	-	-	-	-	-	-	-	-	-
Diptera												
Chaoborus punctipennis	189	38	1021	359	832	2627	189	19	1115	76	-	302
Culex sp.	-	-	-	-	-	-	-	-	-	-	-	-
Palpomiya tibialis	19	-	-	-	-	-	-	-	-	-	-	-
Tabanus sp.	-	-	-	-	-	-	-	-	-	-	-	-
Chironomidae												
Chironomus sp. No. 1	-	-	-	-	57	-	19	57	57	-	-	-
Chironomus sp. No. 2	-	-	-	-	19	-	76	19	-	-	-	-
Chironomus (Cryptochironomus)	-	-	-	-	-	-	-	-	-	-	-	-
Chironomus (Dicrotendipes)	-	-	-	-	-	-	-	-	-	627	38	38
Chironomus (Harnischia)	-	-	-	-	-	-	-	-	-	-	-	-
Chironomus (Kiefferulus)	-	-	-	-	-	-	-	-	19	-	-	-
Chironomus tentans	132	19	19	95	151	19	240	132	76	513	19	57
Clinotanypus sp.	-	-	-	-	-	-	-	-	-	-	-	-
Glyptotendipes sp.	-	-	-	-	-	-	-	-	-	-	-	-
Goeldichironomus sp.	19	-	-	-	-	-	-	-	-	-	-	-
Nannocladius sp.	-	-	-	-	-	-	-	-	-	-	-	-
Orthocladius sp.	-	-	-	-	-	-	-	-	-	19	-	-
Paralauterborniella sp.	-	-	-	-	-	-	-	-	-	-	-	-
Pentaneura flavifrons	-	-	-	-	-	-	-	-	-	-	-	-
Polypedilum sp.	-	-	-	-	-	-	-	-	-	-	-	-
Procladius sp.	-	-	-	-	19	-	19	-	-	152	-	38
Pseudochironomus sp.	-	-	-	-	-	-	-	-	-	-	-	-
Stenochironomus sp.	-	-	-	-	-	-	-	-	-	-	-	-
Tanytarsus sp.	-	-	-	-	-	-	-	-	-	-	-	-
Tanypus sp.	-	-	38	-	19	-	-	-	-	-	-	-
Oligochaeta												
Tubificidae	-	-	-	-	19	38	-	19	-	95	-	38
Basommatophora												
Physa sp.	-	-	-	-	-	-	-	-	-	-	-	-
Sphaerium sp.	-	-	-	-	-	-	-	-	-	-	-	-
Amphipoda												
Hyallela azteca	-	-	-	-	-	-	-	-	-	-	-	-
Hydracarina	-	-	-	-	-	-	-	-	-	-	-	-
Total number of species	4	2	3	2	7	3	5	5	4	6	2	5
Total number of organisms per square meter	359	57	1078	454	1116	2684	549	246	1267	1482	57	473
Biomass (vol. displacement in ml.)	.15	-	.15	.1	.2	.2	.45	.1	.25	.25	-	.1
$\bar{x}$ Biomass		0.1			.17			.27			.12	

– = negligible biomass

o = no biomass

	9/6			10/12			11/10			12/29		
S		5			7			7			6	
N		1494			4254			2062			2012	

APPENDIX C_{31} (cont.)

QUANTITATIVE BENTHOS RESULTS
(Organisms /m ^{2})

Pond 2

	5/25			7/27			8/8		
	A	B	C	A	B	C	A	B	C
Ephemeroptera									
Caenis sp.	170	151	-	-	-	19	19	-	19
Siphlonurus sp.	-	-	-	-	-	-	-	-	-
Odonata									
Anax junius sp.	-	-	-	-	-	-	-	-	-
Enallagma sp.	-	-	19	-	-	-	-	-	-
Trichoptera									
Leptocella sp.	-	113	-	-	-	-	-	-	-
Coleoptera									
Berosus sp.	-	-	-	-	-	-	-	-	-
Dubiraphia sp.	19	-	-	-	-	-	-	-	-
Onychylis sp.	-	-	-	-	-	-	-	-	-
Peltodytes sp.	-	-	-	-	-	-	-	-	-
Diptera									
Chaoborus punctipennis	-	-	-	170	38	76	95	113	189
Culex sp.	-	-	-	-	19	-	-	-	-
Palpomiya tibialis	-	19	-	-	-	-	38	-	-
Tabanus sp.	-	19	19	-	-	-	-	-	-
Chironomidae									
Chironomus sp. No. 1	-	95	-	-	-	-	-	-	-
Chironomus sp. No. 2	-	132	-	-	-	-	-	-	-
Chironomus (Cryptochironomus)	-	-	-	-	-	-	-	-	-
Chironomus (Dicrotendipes)	-	-	-	-	-	-	19	-	-
Chironomus (Harnischia)	-	-	-	-	-	-	-	-	-
Chironomus (Kiefferulus)	-	-	-	-	-	-	-	-	-
Chironomus tentans	-	-	-	-	-	-	1077	-	57
Clinotanypus sp.	-	19	-	-	-	-	-	-	-
Glyptotendipes sp.	-	-	-	19	-	-	-	-	-
Goeldichironomus sp.	-	-	-	-	-	-	-	-	-
Nannocladius sp.	-	-	-	-	-	-	-	-	-
Orthocladius sp.	-	-	-	-	-	-	-	19	-
Paralauterborniella sp.	-	-	-	-	-	-	-	-	-
Pentaneura flavifrons	-	-	-	-	-	-	-	-	-
Polypedilum sp.	-	-	19	-	-	-	95	-	-
Procladius sp.	-	-	-	-	-	-	57	-	-
Pseudochironomus sp.	-	-	-	-	-	-	-	-	-
Stenochironomus sp.	-	-	-	-	-	19	-	-	-
Tanytarsus sp.	-	-	-	-	-	-	-	-	-
Tanypus sp.	-	-	-	-	-	-	-	-	-
Oligochaeta									
Tubificidae	-	19	151	-	-	-	19	-	19
Basommatophora									
Physa sp.	-	-	-	-	-	-	-	-	-
Sphaerium sp.	-	-	-	-	-	-	-	-	-
Amphipoda									
Hyallela azteca	-	-	-	-	-	-	19	-	-
Hydracarina	-	-	-	-	-	-	-	-	-
Total number of species	2	8	4	2	2	3	9	2	4
Total number of organisms per square meter	189	567	208	189	57	114	1438	132	284
Biomass (vol. displacement in ml.)	.05	-	.05	.02	0	0	-	-	-
$\bar{x}$ Biomass		.03			.01			-	

– = negligible biomass

o = no biomass

S		11			5			10	
H		964			360			1854	

APPENDIX C_{11} (cont.)

QUANTITATIVE BENTHOS RESULTS

(Organisms /m ^{2})

Pond 2

		9/6			10/12			11/10			12/29	
	A	B	C	A	B	C	A	B	C	A	B	C
Ephemeroptera												
Caenis sp.	-	-	-	-	-	-	-	-	-	-	-	-
Siphlonurus sp.	-	-	-	-	-	-	-	-	-	-	-	-
Odonata												
Anax junius sp.	-	-	-	-	-	-	-	-	-	-	-	-
Enallagma sp.	-	-	-	-	-	-	-	-	-	-	-	-
Trichoptera												
Leptocella sp.	-	-	-	-	-	-	-	-	-	-	-	-
Coleoptera												
Berosus sp.	-	-	-	-	-	-	-	-	-	-	-	-
Dubiraphia sp.	-	-	-	-	-	-	-	-	-	-	19	-
Onychylis sp.	-	-	-	-	-	-	-	-	-	-	-	-
Peltodytes sp.	-	-	-	-	-	-	-	-	-	-	-	-
Diptera												
Chaoborus punctipennis	95	454	265	57	1172	=	113	1569	1758	19	359	416
Culex sp.	-	-	-	-	-	-	-	-	-	-	-	-
Palpomiya tibialis	-	-	-	-	-	-	-	-	-	38	19	151
Tabanus sp.	-	-	-	-	-	-	-	-	-	-	-	-
Chironomidae												
Chironomus sp. No. 1	76	-	-	170	-	57	38	-	-	-	-	-
Chironomus sp. No. 2	19	-	-	170	-	38	19	19	38	-	-	-
Chironomus (Cryptochironomus)	-	-	-	-	-	-	-	-	-	38	-	57
Chironomus (Dicrotendipes)	-	-	-	-	-	-	-	-	-	359	189	19
Chironomus (Harnischia)	-	-	-	-	-	-	-	-	-	-	-	-
Chironomus (Kiefferulus)	-	-	-	-	-	-	19	-	-	-	-	-
Chironomus tentans	132	95	38	19	567	416	189	397	1621	1550	302	208
Clinotanypus sp.	-	-	-	-	-	-	-	-	-	-	-	-
Glyptotendipes sp.	-	-	-	-	-	-	-	-	-	-	-	-
Goeldichironomus sp.	38	-	-	-	-	-	-	-	-	-	-	-
Nannocladius sp.	-	-	-	-	-	-	-	-	-	-	-	-
Orthocladius sp.	-	-	-	-	-	-	-	-	-	19	-	-
Paralauterborniella sp.	-	-	-	-	-	-	-	-	-	-	-	-
Pentaneura flavifrons	-	-	-	-	-	-	-	-	-	-	-	-
Polypedilum sp.	-	19	-	-	-	-	-	-	-	-	-	-
Procladius sp.	-	-	-	-	-	-	-	19	19	132	132	38
Pseudochironomus sp.	-	-	-	-	-	-	-	-	-	-	-	-
Stenochironomus sp.	-	-	-	-	-	-	-	-	-	-	-	-
Tanytarsus sp.	-	-	-	-	-	-	-	-	-	-	-	-
Tanypus sp.	-	-	-	-	-	-	-	19	-	-	-	-
Oligochaeta												
Tubificidae	19	-	-	-	19	-	-	-	-	132	95	132
Basommatophora												
Physa sp.	-	-	-	-	-	-	-	-	-	-	-	-
Sphaerium sp.	-	-	-	-	-	-	-	-	-	-	-	-
Amphipoda												
Hyallela azteca	-	-	-	-	-	-	-	-	-	-	-	-
Hydracarina	-	-	-	-	-	-	-	-	-	-	-	-
Total number of species	6	3	2	4	3	3	4	4	3	8	7	7
Total number of organisms per square meter	376	568	303	416	1758	511	387	2025	2836	2287	1115	1021
Biomass (vol. displacement in ml.)	-	.1	.02	.02	.0	-	.20	.1	.05	.15	.1	.1
$\overline{x}$ Biomass		.04			.01			.12			.12	
– = neglibible biomass												
o = no biomass												
S		7			5			7			9	
N		1250			2685			5239			4423	

QUANTITATIVE BENTHOS RESULTS

(Organisms /m²)

Pond 3

	5/25			7/27			8/8		
	A	B	C	A	B	C	A	B	C
Ephemeroptera									
Caenis sp.	-	-	-	-	-	-	-	19	-
Siphlonurus sp.	-	-	-	-	19	-	-	-	-
Odonata									
Anax junius sp.	-	-	-	-	-	-	-	-	-
Enallagma sp.	-	-	-	-	-	-	-	-	-
Trichoptera									
Leptocella sp.	-	-	-	-	-	-	-	-	-
Coleoptera									
Berosus sp.	-	19	-	-	-	-	-	-	-
Dubiraphia sp.	-	-	-	-	-	-	-	-	-
Onychylis sp.	-	-	-	-	-	-	-	19	-
Peltodytes sp.	-	19	-	-	-	-	-	-	-
Diptera									
Chaoborus punctipennis	-	-	-	-	-	57	-	57	-
Culex sp.	-	-	-	-	-	-	-	-	-
Palpomiya tibialis	19	-	-	-	-	-	-	-	19
Tabanus sp.	-	-	-	-	-	-	-	-	-
Chironomidae									
Chironomus sp. No. 1	-	-	-	-	-	-	-	-	-
Chironomus sp. No. 2	-	-	-	-	-	-	-	-	-
Chironomus (Cryptochironomus)	-	-	-	-	-	-	-	-	-
Chironomus (Dicrotendipes)	-	-	-	-	-	-	-	-	-
Chironomus (Harnischia)	-	-	-	-	-	-	-	-	-
Chironomus (Kiefferulus)	-	-	-	-	-	-	-	-	-
Chironomus tentans	38	-	-	57	-	-	38	-	19
Clinotanypus sp.	-	-	-	-	-	-	-	-	-
Glyptotendipes sp.	-	-	-	-	-	-	-	-	-
Goeldichironomus sp.	-	-	-	-	-	-	-	-	-
Nannocladius sp.	-	-	-	-	-	-	-	-	-
Orthocladius sp.	-	-	-	-	-	-	-	-	-
Paralauterborniella sp.	-	-	-	-	-	-	-	-	-
Pentaneura flavifrons	-	-	-	-	-	-	-	-	-
Polypedilum sp.	-	-	-	19	-	-	-	-	-
Procladius sp.	-	-	-	-	-	-	-	-	-
Pseudochironomus sp.	-	-	-	-	-	-	-	-	-
Stenochironomus sp.	-	-	-	-	-	-	-	-	-
Tanytarsus sp.	-	-	-	-	-	-	-	-	-
Tanypus sp.	-	-	19	-	-	-	-	-	-
Oligochaeta									
Tubificidae	38	-	-	-	19	-	-	-	-
Basommatophora									
Physa sp.	-	-	-	-	-	-	-	-	-
Sphaerium sp.	19	-	-	-	-	-	-	-	-
Amphipoda									
Hyallela azteca	-	-	359	-	-	-	-	-	-
Hydracarina	-	-	-	-	-	-	-	-	-
Total number of species	4	2	2	2	2	1	1	3	2
Total number of organisms per square meter	114	38	378	76	38	57	38	95	38
Biomass (vol. displacement in ml.)	.05	.15	.15	.05	0	-	.1	.05	0
$\bar{x}$ Biomass		.12			.02			.05	
S		8			5			5	
N		527			171			171	

– = negligible biomass

o = no biomass

APPENDIX C_{31} (cont.)

QUANTITATIVE BENTHOS RESULTS
(Organisms /m^2)

	Pond 4											
		9/6			10/12			11/10			12/29	
	A	B	C	A	B	C	A	B	C	A	B	C
Ephemeroptera												
Caenis sp.	-	-	-	-	-	-	-	-	-	-	-	-
Siphlonurus sp.	-	-	-	-	-	-	-	-	-	-	-	-
Odonata												
Anax junius sp.	-	-	-	-	-	-	-	-	-	-	-	-
Enallagma sp.	-	-	-	-	-	-	-	-	-	-	-	-
Trichoptera												
Leptocella sp.	-	-	-	-	-	-	-	-	-	-	-	-
Coleoptera												
Berosus sp.	-	-	-	-	-	-	-	-	-	-	-	-
Dubiraphia sp.	-	-	-	-	-	-	-	-	-	-	-	-
Onychylis sp.	-	-	-	-	-	-	-	-	-	-	-	-
Peltodytes sp.	-	-	-	-	-	-	-	-	-	-	-	-
Diptera												
Chaoborus punctipennis	38	-	-	-	567	548	95	170	321	38	-	-
Culex sp.	-	-	-	-	-	-	-	-	-	-	-	-
Palpomiya tibialis	-	-	-	-	-	19	-	-	-	-	-	-
Tabanus sp.	-	-	-	-	-	-	-	-	-	-	-	-
Chironomidae												
Chironomus sp. No. 1	-	-	-	-	-	-	-	-	-	-	-	-
Chironomus sp. No. 2	-	-	-	-	-	-	-	-	-	-	-	-
Chironomus (Cryptochironomus)	-	-	-	-	-	-	-	-	-	-	-	-
Chironomus (Dicrotendipes)	-	-	-	-	-	-	-	-	-	-	-	-
Chironomus (Harnischia)	-	-	-	-	-	-	-	-	-	-	-	-
Chironomus (Kiefferulus)	-	-	-	-	-	-	-	-	-	-	-	-
Chironomus tentans	19	-	113	95	57	-	57	76	19	151	265	76
Clinotanypus sp.	-	-	-	-	-	-	-	-	-	-	-	-
Glyptotendipes sp.	-	-	-	-	-	-	-	-	-	-	-	-
Goeldichironomus sp.	-	-	-	-	-	-	-	-	-	-	-	-
Nannocladius sp.	-	-	-	-	-	-	-	-	-	-	-	-
Orthocladius sp.	-	-	-	-	-	-	-	-	-	-	-	-
Paralauterborniella sp.	-	-	-	-	-	-	-	-	-	-	-	-
Pentaneura flavifrons	-	-	-	-	-	-	-	-	-	-	-	-
Polypedilum sp.	-	-	-	-	-	-	-	-	-	-	-	-
Procladius sp.	-	-	-	-	-	-	38	-	-	19	-	-
Pseudochironomus sp.	-	-	-	-	-	-	-	-	-	-	-	-
Stenochironomus sp.	-	-	-	-	-	-	-	-	-	-	-	-
Tanytarsus sp.	-	-	-	-	-	-	-	-	-	-	-	-
Tanypus sp.	-	-	-	-	19	-	-	-	-	-	-	-
Oligochaeta												
Tubificidae	-	-	76	-	76	321	-	19	113	-	57	1418
Basommatophora												
Physa sp.	-	-	-	-	-	-	-	-	-	-	-	-
Sphaerium sp.	-	-	-	-	-	-	-	-	-	-	-	-
Amphipoda												
Hyallela azteca	-	-	-	-	-	-	-	-	-	-	-	-
Hydracarina	-	-	-	-	-	-	-	-	-	-	-	-
Total number of species	2	0	2	1	4	3	3	3	3	3	2	2
Total number of organisms per square meter	57	0	189	95	719	888	190	265	453	208	322	1494
Biomass (vol. displacement in ml.)	-	0	.15	.05	.15	.1	.05	.1	.06	.08	.15	.15
$\bar{X}$ Biomass		.05			0.1			.02			.13	
- = negligible biomass												
o = no biomass												
S		3			5			4			4	
N		246			1702			908			2024	

APPENDIX C_{31} (cont.)

QUANTITATIVE BENTHOS RESULTS

(Organisms /m)

Pond 4

	5/25			7/27			8/8		
	A	B	C	A	B	C	A	B	C
Ephemeroptera									
Caenis sp.	57	76	57	-	-	19	-	-	-
Siphlonurus sp.	-	-	-	-	-	-	-	-	-
Odonata									
Anax junius sp.	-	-	19	-	-	-	-	-	-
Enallagma sp.	-	19	57	-	-	-	-	-	-
Trichoptera									
Leptocella sp.	57	-	57	-	-	-	-	-	-
Coleoptera									
Berosus sp.	-	-	-	-	-	-	-	-	-
Dubiraphia sp.	-	-	-	-	-	-	-	-	-
Onychylis sp.	-	-	-	-	-	-	-	-	-
Peltodytes sp.	-	-	-	-	-	-	-	-	-
Diptera									
Chaoborus punctipennis	-	-	-	38	38	-	38	38	-
Culex sp.	-	-	-	-	-	-	-	-	-
Palpomiya tibialis	-	-	-	-	19	-	-	-	19
Tabanus sp.	-	-	19	-	-	-	-	-	-
Chironomidae									
Chironomus sp. No. 1	-	-	-	-	-	-	-	-	-
Chironomus sp. No. 2	-	-	-	-	-	-	-	-	-
Chironomus (Cryptochironomus)	-	-	-	-	-	19	-	-	-
Chironomus (Dicrotendipes)	-	-	-	-	-	-	-	-	-
Chironomus (Harnischia)	-	-	-	-	-	-	-	-	-
Chironomus (Kiefferulus)	-	-	-	-	-	-	-	-	-
Chironomus tentans	19	-	-	-	95	38	38	76	265
Clinotanypus sp.	-	-	-	-	-	-	-	-	-
Glyptotendipes sp.	-	-	-	-	-	-	-	-	-
Goeldichironomus sp.	-	-	-	-	-	-	-	-	-
Nannocladius sp.	-	-	-	-	19	-	-	-	-
Orthocladius sp.	-	-	-	-	-	-	19	-	-
Paralauterborniella sp.	-	-	-	-	-	-	-	-	-
Pentaneura flavifrons	-	-	95	-	-	-	-	-	-
Polypedilum sp.	-	-	-	-	-	19	-	-	-
Procladius sp.	-	-	-	-	19	57	-	-	-
Pseudochironomus sp.	-	-	-	-	19	-	-	-	-
Stenochironomus sp.	-	-	-	-	-	-	-	-	-
Tanytarsus sp.	-	-	-	-	-	-	-	-	-
Tanypus sp.	-	-	-	-	-	-	-	-	-
Oligochaeta									
Tubificidae	-	-	19	-	-	-	19	76	38
Basommatophora									
Physa sp.	76	-	19	-	-	-	-	-	-
Sphaerium sp.	-	-	-	-	-	-	-	-	-
Amphipoda									
Hyallela azteca	491	19	95	-	-	76	-	-	-
Hydracarina	-	19	-	-	-	-	-	-	-
Total number of species	5	4	9	1	6	5	4	3	4
Total number of organisms per square meter	700	133	437	38	209	209	114	171	360
Biomass (vol. displacement in ml.)	.6	.1	.2	-	.02	-	-	.05	.1
$\bar{x}$ Biomass		0.3			.01			.05	
- = negligible biomass									
0 = no biomass									
S		11			9			6	
N		1270			456			645	

APPENDIX C_{31} (cont.)

QUANTITATIVE BENTHOS RESULTS

(Organisms $/m^2$)

Pond 3

	9/6			10/12			11/10			12/29		
	A	B	C	A	B	C	A	B	C	A	B	C
Ephemeroptera												
Caenis sp.	-	-	-	-	-	-	-	-	-	-	-	-
Siphlonurus sp.	-	-	-	-	-	-	-	-	-	-	-	-
Odonata												
Anax junius sp.	-	-	-	-	-	-	-	-	-	-	-	-
Enallagma sp.	-	-	-	-	-	-	-	-	-	-	-	-
Trichoptera												
Leptocella sp.	-	-	-	-	-	-	-	-	-	-	-	-
Coleoptera												
Berosus sp.	-	-	-	-	-	-	-	-	-	-	-	-
Dubiraphia sp.	-	-	-	-	-	-	-	-	-	-	-	-
Onychylis sp.	-	-	-	-	-	-	-	-	-	-	-	-
Peltodytes sp.	-	-	-	-	-	-	-	-	-	-	-	-
Diptera												
Chaoborus punctipennis	-	38	57	95	-	57	19	19	-	-	113	38
Culex sp.	-	-	-	-	-	-	-	-	-	-	-	-
Palpomiya tibialis	-	-	-	-	-	-	-	-	19	-	-	-
Tabanus sp.	-	-	-	-	-	-	-	-	-	-	-	-
Chironomidae												
Chironomus sp. No. 1	-	-	-	-	-	-	19	19	-	-	-	-
Chironomus sp. No. 2	-	-	-	-	-	-	-	-	-	-	-	-
Chironomus (Cryptochironomus)	-	-	-	-	-	-	-	-	-	-	-	-
Chironomus (Dicrotendipes)	-	-	-	-	-	-	-	-	-	-	-	-
Chironomus (Harnischia)	-	-	-	-	-	-	-	-	-	-	-	-
Chironomus (Kiefferulus)	-	-	-	-	-	-	-	-	-	-	-	-
Chironomus tentans	19	95	-	-	-	-	151	113	19	416	189	170
Clinotanypus sp.	-	-	-	-	-	-	-	-	-	-	-	-
Glyptotendipes sp.	-	-	-	-	-	-	-	-	-	-	-	-
Goeldichironomus sp.	-	-	-	-	-	-	-	-	-	-	-	-
Nannocladius sp.	-	-	-	-	-	-	-	-	-	-	-	-
Orthocladius sp.	-	19	-	-	-	-	-	-	-	-	-	-
Paralauterborniella sp.	-	-	-	-	-	-	-	-	-	-	-	-
Pentaneura flavifrons	-	-	-	-	-	-	-	-	-	-	-	-
Polypedilum sp.	-	19	-	-	-	-	-	-	-	-	-	-
Procladius sp.	-	-	-	-	-	-	-	-	-	-	-	-
Pseudochironomus sp.	-	-	-	-	-	-	-	-	-	-	38	-
Stenochironomus sp.	-	-	-	-	-	-	-	-	-	-	-	-
Tanytarsus sp.	-	-	-	-	-	-	-	-	-	-	-	-
Tanypus sp.	-	-	-	-	-	-	-	-	-	-	-	-
Oligochaeta												
Tubificidae	-	-	95	-	-	-	19	-	38	19	-	57
Basommatophora												
Physa sp.	-	-	-	-	-	-	-	-	-	-	-	-
Sphaerium sp.	-	-	-	-	-	-	-	-	-	-	-	-
Amphipoda												
Hyallela azteca	-	-	-	-	-	-	-	-	-	-	-	-
Hydracarina	-	-	-	-	-	-	-	-	-	-	-	-
Total number of species	1	4	2	1	0	1	4	3	3	2	3	3
Total number of organisms per square meter	19	171	152	95	0	57	208	151	76	435	340	265
Biomass (vol. displacement in ml.)	.15	.2	.15	-	.3	1.5	.25	1.5	2.4	2.2	.25	.30
$\bar{x}$ Biomass		.17			.6			1.38			0.92	
– = negligible biomass												
o = no biomass												
S		5			1			5			4	
N		342			152			435			1040	

APPENDIX C_{32}

1972 SHANNON WEAVER DIVERSITY CALCULATIONS ON BENTHIC COMMUNITY

	Pond #			
Date	1	2	3	4
5/25	1.75	1.94	1.24	1.72
7/27	1.64	0.81	1.46	2.01
8/8	0.90	1.27	1.46	1.10
9/6	0.60	1.08	1.40	0.99
10/12	0.46	1.17	0.00	0.93
11/10	1.22	0.84	1.11	0.99
12/29	1.46	1.59	0.81	0.69
Annual Mean Diversity Values	1.15	1.24	1.07	1.20

APPENDIX C_{33}

Date	Pond 1		Pond 2		Pond 3		Pond 4	
	$S-1/1_{N}N$	$S/\sqrt{N}$	$S-1/1_{N}N$	$S/\sqrt{N}$	$S-1/1_{N}N$	$S/\sqrt{N}$	$S-1/1_{N}N$	$S/\sqrt{N}$
5/25	1.13	0.26	1.46	0.35	1.12	0.35	1.40	0.31
7/27	0.99	0.34	0.68	0.26	0.79	0.38	1.46	0.46
8/8	0.55	0.14	1.20	0.23	0.78	0.38	0.62	0.20
9/6	0.55	0.13	0.84	0.20	0.69	0.27	0.36	0.19
10/12	0.72	0.11	0.51	0.10	0.0000	0.08	0.54	0.12
11/10	0.79	0.15	0.69	0.10	0.66	0.24	0.44	0.13
12/29	0.66	0.14	0.95	0.14	0.43	0.12	0.39	0.09

1972 Richness Calculations

APPENDIX C_{34}

1973 SPECIES COMPOSITION AND BIOMASS

BENTHOS (organisms/m^2)

	Pond 1			Pond 2			Pond 3			Pond 4		
15 Apr 73	A	B	C	A	B	C	A	B	C	A	B	C
Diptera												
Chaoborus punctipennis			247		95		19				19	
Palpomyia tibialis				38								
Chironomus tentans	19	380	38	399	190	247	19		95	19	19	19
Procladius sp.				19	38	19						
Oligochaeta												
Tubificidae		57	19				95				19	114
Peloscolex freyi		19	19		38							
Total Number of species	1	3	4	3	4	2	3	0	1	1	3	2
Total Number of individuals per square meter	19	456	323	456	361	266	133	0	95	19	57	133
Biomass (volume displaced in mls)	†	0.25	0.25	0.25	0.20	0.10	†	0.00	†	†	†	†
$\overline{X}$ Biomass		0.16			0.18			†			†	

†= negligible biomass (<0.01 ml displaced)

0.00 = no biomass

APPENDIX C_{34} (cont.)

1973 SPECIES COMPOSITION AND BIOMASS

BENTHOS (organisms/m^2)

	Pond 1			Pond 2			Pond 3			Pond 4		
18 Jun 73	A	B	C	A	B	C	A	B	C	A	B	C
Diptera												
Chaoborus punctipennis					19							
Palpomyia tibialis			19									
Chironomus tentans	95	95	19	437	703	171	38		38	19		
Glyptotendipes sp.				38								
Chironomus sp. 1		19										
Tanypus sp.	19							19				
Total number of species	2	2	2	2	2	1	1	1	1	1	0	0
Total number of individuals per square meter	114	114	38	475	722	171	38	19	38	19	0	0
Biomass (volume displacement in mls)	0.05	0.05	0.01	0.30	0.65	0.15	0.01	0.01	0.01	0.01	0.00	0.00
$\overline{X}$ biomass		0.04			0.37			0.01			†	
24 Jul 73												
Diptera												
Chaoborus punctipennis	513	570	1292	1254	608	494	76	76	19	19	228	
Palpomyia tibialis					19							
Chironomus tentans		19	19	247	133	76					38	19
Procladius sp.				19								
Oligochaeta												
Tubificidae												
Peloseolex freyi			19									
Total number of species	1	2	3	3	3	2	1	1	1	1	2	1
Total number of individuals per square meter	513	589	1331	1520	760	570	76	76	19	19	266	19
Biomass (vol. displaced in mls)	0.05	0.05	0.10	0.25	0.15	0.10	0.01	0.01	†	0.00	0.05	0.01
$\overline{X}$ biomass		0.07			0.17			0.01			0.02	

APPENDIX C_{34} (cont.)

1973 SPECIES COMPOSITION AND BIOMASS

BENTHOS (organisms/m^2)

	Pond 1			Pond 2			Pond 3			Pond 4		
23 Aug 73	A	B	C	A	B	C	A	B	C	A	B	C
Diptera												
Chaoborus punctipennis	3857	874	3173	1083	893	589	38	133	323	19	494	38
Palpomyia tibialis	19		38	19		152			38	76		19
Chironomus tentans		57		171	76		19		38			19
Glyptotendipes sp.		38										
Parachironomus sp.											19	
Procladius sp.		38		209		38						
Chironomus sp.				19								
Tanypus sp.		19	57	19	57							
Oligochaeta												
Tubificidae												
Peloscolex freyi	19	285	19			19	57	114	152		38	76
Gastropoda												
Stagnicola sp.	19											
Total number of species	4	6	4	6	3	4	3	2	4	2	3	4
Total number of individuals per square meter	3914	1311	3287	1520	1026	798	114	247	551	95	551	152
Biomass (volume displaced in mls)	0.25	0.10	0.20	0.15	0.05	0.10	0.01	0.01	0.10	0.01	0.01	0.01
$\overline{X}$ Biomass		0.18		0.10				0.04			0.01	

APPENDIX C$_{35}$
BENTHOS - 1973
Richness

Date		Pond 1	Pond 2	Pond 3	Pond 4
15 May 73	s	4	5	3	3
	N	798	1083	228	209
	$\sqrt{N}$	28.24	32.91	15.10	14.46
	lnN	6.68	6.99	5.43	5.34
	$\frac{s}{\sqrt{N}}$ richness	0.142	0.152	0.199	0.207
	$\frac{s-1}{\ln N}$ richness	0.449	0.572	0.368	0.375
	$\overline{X}$ biomass	0.16	0.18	+	+
18 Jun 73	s	4	3	2	1
	N	266	1368	95	19
	$\sqrt{N}$	16.31	36.99	9.75	4.36
	ln N	5.58	7.22	4.55	2.94
	$\frac{s}{\sqrt{N}}$ richness	0.245	0.081	0.205	0.299
	$\frac{s-1}{\ln N}$ richness	0.538	0.277	0.220	0.000
	$\overline{X}$ biomass	0.071	0.37	0.01	+
24 Jul 73	s	3	4	1	2
	N	2433	2850	171	304
	$\sqrt{N}$	49.32	53.38	13.08	17.44
	lnN	7.80	7.96	5.14	5.72
	$\frac{s}{\sqrt{N}}$ richness	0.061	0.075	0.076	0.115
	$\frac{s-1}{\ln N}$ richness	0.256	0.377	0.000	0.175
	$\overline{X}$ biomass	0.07	0.17	0.1	0.02
23 Aug 73	s	8	7	4	5
	N	8512	3344	912	798
	$\sqrt{N}$	92.26	57.83	30.20	28.25
	lnN	9.05	8.12	6.82	6.68
	$\frac{s}{\sqrt{N}}$ richness	0.087	0.121	0.132	0.177
	$\frac{s-1}{\ln N}$ richness	0.773	0.739	0.440	0.599
	$\overline{X}$	0.18	0.1	0.04	0.01

APPENDIX C_{36}

1973 SHANNON WEAVER DIVERSITY CALCULATIONS ON BENTHIC COMMUNITY

	Pond #			
Date	1	2	3	4
5/15	1.06	0.83	0.92	0.86
6/18	0.75	0.20	0.50	0.0
7/24	0.13	0.52	0.0	0.48
8/23	0.36	0.89	1.01	0.97
Mean ($\bar{X}$) Diversity Value	0.58	0.61	0.61	0.58

APPENDIX C_{37}

WRONG CHOICES (AS PERCENT OF TOTAL POSSIBLE) COMPARED TO VOLUME OF FUEL USED TO DATE

Pond	Gals. full burned/10^6 gals. diluent water	Percent of wrong choices on taste identification
Non-leaded	1.4	33
Leaded	1.4	66
Non-leaded	1.5	71
Leaded	1.5	86
Non-leaded	2.8	50
Leaded	2.8	63
Non-leaded	4.0	30
Leaded	4.0	78
Non-leaded	4.2	88
Leaded	4.2	88
Non-leaded	11.2	71
Leaded	11.2	71
Non-leaded	76.9	71
Leaded	76.9	71
Non-leaded	110.5	86
Leaded	110.5	71
Non-leaded $\overline{X}$		62.5
Leaded $\overline{X}$		74.3